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Bryophytes of Fens in the Northern Sierra Nevada

An Illustrated Field Booklet

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Abstract

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The author presents a photographic field guide for non-specialists to some common and uncommon bryophytes found in montane fens in the northern Sierra Nevada of the Plumas and Tahoe National Forests, and the Lake Tahoe Basin Management Unit of California, and a limited portion of the Humboldt-Toiyabe National Forest on the Carson City District in Nevada. General characteristics of bryophytes are presented. Treatment is not comprehensive for the region, but depicts 24 species of bryophytes, including seven liverworts, eleven acrocarpous mosses (three *Sphagnum*), and six pleurocarpous mosses. The field guide includes keys to groups of bryophytes and to species within those groups. Additional notes for laboratory determination of difficult species are provided.

Keywords: bryophyte, moss, liverwort, hornwort, *Sphagnum*, peatland, wetland, fen, Sierra Nevada, California, Tahoe National Forest, Plumas National Forest, and LTBMU.

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I. Introduction and Need for Study

The study of bryophytes (mosses, liverworts, and hornworts) is a specialized field of botany. The three groups of bryophytes have traditionally been placed and treated together because of similarities in their growth forms, morphological complexity, life cycle, and mechanisms of reproduction. Many people recognize that bryophytes include mosses, liverworts and hornworts; however, few people can place a plant into its primary group or identify these very small plants to genus or species. Identification to genus and species is complicated by a number of factors including: access to references and herbarium specimens, the need for special training in bryologic techniques, and the need for expensive optical equipment and materials.

Development of tools for bryophyte identification has recently improved through the availability of several publications including: illustrated glossaries (Malcolm & Malcolm 2000, 2006); A Guide to California Mosses (Malcolm *et al.* 2009); keys and catalogues of mosses, liverworts and hornworts of California (Norris & Shevock 2004a, 2004b, Doyle & Stotler 2006); Flora of North America – Volume 27, continuing online provisional treatments), and a field guide to the liverwort genera of the Pacific Northwest (Schofield 2002). However, field technicians continue to need field guides that provide the information needed to facilitate identification of bryophytes in the field. This guide was developed to assist field going personnel with the identification of peatland/fen bryophytes and is intended to serve as an adjunct to the recent USDA publication titled *Assessing Proper Functioning Condition for Fen Areas in the Sierra Nevada and Southern Cascade Ranges in California* (Weixelman and Cooper 2009).

Peatlands and fens are considered wetlands and fens are a specific type of peatland that have perennially saturated soils that are fed almost entirely by ground water. (In contrast, bogs are fed by rain water.) The peat in these plant communities is typically formed from clonal sedges, rushes, spike rushes and mosses. Peatlands are classified as fens when the organic soils or histosols are at least 40 cm deep. Most fens in the Sierra Nevada of California are relatively small with many less than 1 hectare in size. Many of the Sierra Nevada fens exhibit a very long period of hydrologic and geomorphic stability (Bartolome et al. 1990).

The author of this guide surveyed 22 fens located within the Plumas and Tahoe National Forests, the Lake Tahoe Basin Management Unit of California; and the Carson Ranger District on the Humboldt-Toiyabe National Forest, in the state of Nevada.

Twenty-four of the approximately 80 common and rare species of mosses and liverworts identified from peatlands within the northern Sierra Nevada, California are included in this field guide. The author considers the bryophyte diversity observed in this study as comparable with other Northern Hemisphere peatland complexes in central Sweden and northern Ontario, Canada. The keys provided in this field guide are tailored specifically for the 24 species identified within this guide. This field guide includes both common and rare bryophytes. It is recommended that other identification resources be used when bryophytes found in the field do not fit the descriptions found in this guide.

II. Recognizing Bryophytes

This field guide is intended for use by non-specialists in the field of bryology. The key identification characteristics for each of the 24 bryophytes are provided in short and concise descriptions. A good hand lens or loupe of at least 10X magnification is needed for bryophyte identification, but 15X to 20X magnification is preferable. Backlighting the specimen with bright light is also recommended. Examining the specimen in both moist and dry conditions may also be helpful.

To begin, look for plants that obviously are not algae, lichens, fungi, ferns, club-mosses, spike-mosses, or other spore-producing vascular plants. Look for green (usually), small plants with thalloid (flattened, ribbon-like or strap-like without discernable leaves) or *leafy* growth forms, that are attached to substrates by simple hair-like rhizoids that are one-cell wide (Note: a few bryophytes are not attached and are floating aquatic forms.) Remember that bryophytes are much less structurally complex than vascular plants so roots, woody structures, and vascular (conducting) tissues will not be present.

Bryophytes also differ from vascular plants in their reproductive methods. When sexual reproduction occurs, dispersal is by means of spores. Spores are produced in single, capsule-like sporangia (hornworts are an exception). Sporangia are not arranged in cone-like strobili, as are the club-mosses and spike-mosses and do not occur on the surfaces or edges of leaves, as in ferns.

Bryophytes exhibit a distinct alternation of generations. The dominant phase called the gametophyte is haploid. The less obvious phase called the sporophyte is diploid. The dominant haploid phase of a bryophyte produces sexual gametes, i.e. eggs and sperm. The diploid phase produces spores. The female sex organs are called archegonia, and the male sex organs are called antheridia. Sporophytes develop as a result of fusion of the eggs and sperm.

A. Recognizing Liverworts and Hornworts

Hornworts and two of the three major groups of liverworts have thalloid or flat, ribbon-like or strap-like growth forms. This growth form is not easily recognizable when the plants are dry. This guide does not address hornworts since no hornworts were found in the sampled fens.

The two groups of thalloid liverworts can have either a simple or complex structure. Both forms tend to be dichotomously branched. Simple thalloid liverworts lack internal air chambers. Complex thalloid liverworts have internal air chambers. In gross appearance, simple thalloid liverworts are rather uniform in texture on the upper surface of the thallus. In contrast, complex thalloid liverworts have a distinct hexagonal patterning on the upper surface, and each hexagon has a central opening or pore that allows gas exchange to the internal air chamber. This difference is easily seen with the naked eye, or at least with low magnification. Two genera and species of simple thalloid liverworts are treated in this guide, but only one complex thalloid liverwort is considered. In the simple thalloid liverworts considered, the gametangia are imbedded in the thallus itself, in contrast to the single species of complex liverwort in this

guide, which produces its male and female gametangia (archegonia and antheridia), on elevated, mushroom-like structures called archegoniophores, and antheridiophores, respectively. These distinctive structures have an elongated stalk and terminal "cap."

Leafy liverworts have stems with leaves attached. This may cause some confusion with mosses, but with only a little experience, the differences will become readily apparent. The leaves of leafy liverworts are almost always two-ranked, or flattened into a plane and attached on each side of the stem; relatively few mosses have leaves flattened and arranged in two ranks. The leaves of leafy liverworts are sometimes lobed or divided, and there is *never* any midrib in the leaf. Mosses do not have divided leaves, and most have a midrib. The cells of the leaves of leafy liverworts are isodiametric (rounded), whereas those of most mosses tend to be quadrate, rectangular, or elongated to linear. Sometimes the bottom of the stem of some leafy liverworts has a single row of underleaves that are closely appressed to the stem, and these are often divided. Mosses do not exhibit these underleaves. Leafy liverworts range from very small, around 1 mm wide, to moderately large, around 5 mm wide.

B. Recognizing Mosses

Mosses are *always leafy* and there is great variability around that common feature. However, unlike the leafy liverworts, the leaves of most species of moss have a distinct midrib, called a costa. The costa can be absent, short, double, and sometimes difficult to see. The leaves of mosses are attached spirally around the stem, or may appear flattened into two ranks.

It is important to identify the growth form of a moss. Some mosses are simple, *upright* and *unbranched*, or very *sparsely-branched*. Others are prostrate, creeping, or occasionally erect. Lateral branching can appear "feathery," or plumose. Erect and unbranched to few-branched forms are called acrocarpous mosses, and the mostly prostrate (sometimes erect) and highly branched forms are termed pleurocarpous mosses.

III. Keys and Descriptions

The use of "keys" is a common way of determining plants. Typically, keys are termed *dichotomous*. That is, there are two possible choices, or couplets at each step in the key. With specimen in hand, the idea is to select which of the two choices best describes your plant. The best choice then indicates either the name (or group) of the plant, or leads to another step in the key indicated by a number.

Key to Major Groups of Bryophytes

1 Plants with stems and leaves..... **2**
1' Plants thalloid, i.e., flattened, strap-like, or ribbon-like..... **4**

2 Leaves equally spaced around the stem(s), or if leaves two-ranked, then leaves with a costa and/or leaf cells elongated, and without underleaves; sporophytes when present persisting for weeks to months, or more ..... **Mosses 3**
2' Leaves two-ranked, without any midrib, often rounded, lobed, or divided; leaf cells isodiametric (rounded); underleaves sometimes present.....**Leafy Liverworts**

3 Plants erect, tufted, and only sparingly branched; when present, capsules occur at the tips of the main branches..... **Acrocarpous Mosses**
3' Plants mostly prostrate, matted, and highly branched, occasionally erect; when present, capsules occur on short lateral branches along the main axis of the stem ..... **Pleurocarpous Mosses**

4 Thallus mostly dichotomously (Y-shaped) branched; short lateral branches may be present. Plants are mostly green when fresh, not bluish-green; thallus margin mostly smooth, not eroded or lacerate. Sporophytes when present remain embedded in thallus, or exserted from stalked umbrella-like structures, sporangia globose or ellipsoid, attached to watery and translucent seta, very short-lived, usually only a few days ..... **Thalloid Liverworts**
4' Thallus irregular, not clearly dichotomously branched, often with eroded or lacerate edges; color of fresh thallus often blue-green; cells of fresh thallus speckled (transmitted light) from a single, large chloroplast in each cell; sporophytes linear, elongated from candle-holder-like receptacles above the thallus, resembling small blades of grass, green at first darkening at the tips, and finally becoming black, drying, and persistent .....**Hornworts** (not treated here)

Key to Groups of Liverworts

1 Plants leafy, leaves appearing in two ranks, and never with any midrib... **Leafy Liverworts**
1' Plants thalloid, mostly dichotomously (Y-shaped) branched, short lateral branches may be present..... **2**

2 Plants relatively large, mostly 1 cm wide or more, the dorsal surface with internal air chambers marked by a distinct hexagonal pattern and central pore visible to naked eye, clearly visible at 10X, and thallus always opaque, due to thickness. Elevated, stalked,

umbrella-like reproductive structures bearing archegonia, antheridia, or sporophytes present, or absent..... **Complex Thalloid Liverworts**

2' Plants small, mostly less than 1 cm wide, without internal air chambers; appearing thin and without hexagonal patterning or pores, and generally watery-translucent and grass green[1], when fresh. Archegoniophores and/or antheridiophores (elevated, stalked, umbrella-like reproductive structures) absent..... **Simple Thalloid Liverworts**

Key to Leafy Liverworts

1 Leaves complicate-bilobed (two lobes folded together like a taco shell), the two leaf lobes uneven, the dorsal (upper) lobe clearly smaller then the ventral (lower) lobe, narrowly to broadly ovate (egg-shaped), suborbicular (nearly round) to reniform (kidney-shaped), and with margins strongly serrate (toothed); shoot tips mostly curving downward; perianth (sleeve-like structure) enclosing the female reproductive organs flattened, wide at the mouth..... ***Scapania***

1' Leaves unlobed, or if bilobed (two lobes), the two lobes not folder together; leaf margins not toothed..... **2**

2 Leaves incubous[2] (front margin of leaf lies *over* the rear margin of the next leaf closer to the stem apex)..... ***Calypogeia***

2' Leaves succubous (front margin of leaf lies *under* the rear margin of the next leaf closer to the stem apex)..... **3**

3 Leaves not lobed, rounded; a single row of underleaves (leaves on the underside of the stem) present and conspicuous..... ***Chiloscyphus***

3' Leaves bilobed, the lobes acute; underleaves absent..... ***Cephalozia***

Key to Simple Thalloid Liverworts

1 Thallus less than 2 mm wide; microscopic confirmation of fresh material: cells with 0-5 large, usually brownish oil bodies. ..... ***Riccardia***

1' Thallus 2-9 mm wide, microscopic confirmation of fresh material: cells with 6-30 small, colorless oil bodies **2**

2 Thallus without midrib; male sex organs (antheridia) and female sex organs (archegonia) developing on short lateral branches ..... ***Aneura***

2' Thallus with definite, but poorly delimited midrib; antheridia and archegonia developing on dorsal surface of main axis ..... ***Pellia*** (not treated herein)

---

[1] Plants blue-green to blackish observed on fresh thalli could be hornworts. Look for one or more of the following hornwort characters: roughened surface thallus along its axes; a single large chloroplasts in each cell; irregular, small lobes along thallus margins, additional thallus branching from the dorsal surface of the thallus, or beyond the basic dichotomous form; swellings along the margins of the thallus, these-greenish yellow in fresh thalli; obvious sporophytes, arising as grass-like filaments from the top of the thallus, each imbedded by an involucre at their bases, in the fashion of a candleholder.

[2] One can think of the terms incubous and succubous by analogy with the shingles on a roof. If the stem is growing up toward the roofline, then leaves attached succubous are like shingles that shed water outward and downward. Incubous is analogous to a bad roofing job, one that was done backward, such that water flows inward and under the shingles!

Key to Complex Thalloid Liverworts

1 Archegonia and sporophyte capsules, and antheridia both associated with umbrella-like elevated structures (archegoniophores and antheridiophores, respectively); plants usually with dorsal cup-shaped gemma receptacles on the dorsal surface... ***Marchantia polymorpha***

1' Archegonia and sporophyte capsules *either* associated with umbrella-like elevated structures, *or* imbedded in the thallus; *and* antheridia imbedded in the thallus; Plants without dorsal cup-shaped gemma receptacles..... **Other genera not treated here**

Descriptions of Liverworts

Aneura pinguis (L.) Dumortier [Aneuraceae] See **Plate 1**

(Main reference: Doyle & Stotler 2006 [p 124])
(Additional illustrations: Frey *et al.* 2006 [fig 15 p 46]; Schofield 2002 [p 42]; Smith 1990 [fig 131 p 298]; Watson 1981 [figs 208 pp 422])

A simple thallose liverwort, cosmopolitan in distribution that occurs on damp rock or peat, often among other bryophytes, from sea level to alpine elevations. The genus name means "without a nerve," denoting that the thallus lacks a nervelike, thickened midrib. These are reclining, brittle, sparingly and irregularly branched, light to dark green, or sometimes bluish, described as having a somewhat "greasy luster" to the thalli. Look for the thin thallus that gradually thins to one cell thick toward the margin, and short lateral branches at right angles that bear antheridia and archegonia. *Aneura pinguis* is most likely to be confused with species of *Riccardia* (discussed herein), or *Pellia* (not discussed here, but see Schofield 2002 p 164). *Pellia* has a more evident central nerve and is not greasy looking. *Riccardia* is smaller; with thalli 1-3 mm wide (vs. 4-5 mm for *Aneura*) and more highly branched. Hornworts of the genus *Phaeoceros* resemble *Aneura pinguis*; however, these have colonies of cyanobacteria in the thallus, and a single, large chloroplast in the thallus (use transmitted light to see these features).

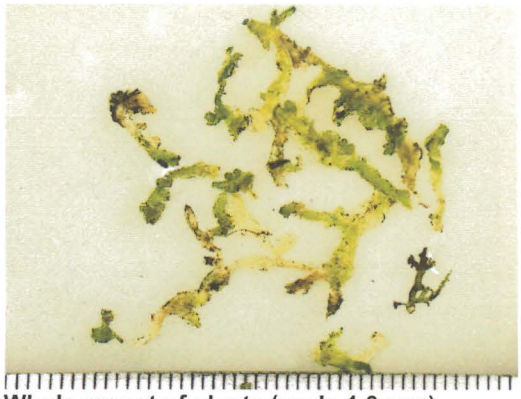
Calypogeia muelleriana (Schiffn.) Mull. Frib. [Calypogeiaceae] See **Plate 2**

(Main reference: Doyle & Stotler 2006 [p 141])
(Additional illustrations: Frey *et al.* 2006 [fig 19 p 57]); Schofield 2002 [p 74]; Smith 1990 [fig 12 p 37]; Watson 1981 [figs 223 pp 444])

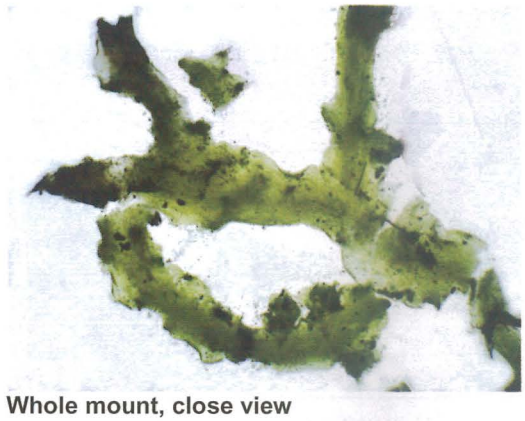
This leafy liverwort ranges from sea level to 2,900 m in elevation. Found in Europe, Asia and North America, on damp decaying logs and organic soils. The leaf insertion is incubous and the leaves are obliquely attached to the stem. Leaves are generally heart shaped with apices rounded or obtuse; underleaves are lobed with lobe apices rounded or obtuse, divided to within 3-6 cells of the rhizoid initial area (where the rhizoids are attached to the stem). Plants are green to yellowish- to whitish-green, and usually shiny when dry. Sporophytes arise from subterranean pouches, or marsupia, from which the genus name is derived, meaning "flower from under the earth."

Plate 1

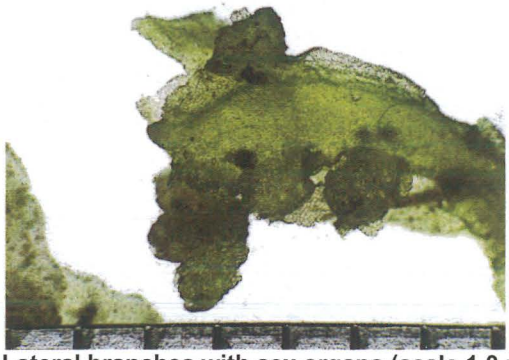
Aneura pinguis



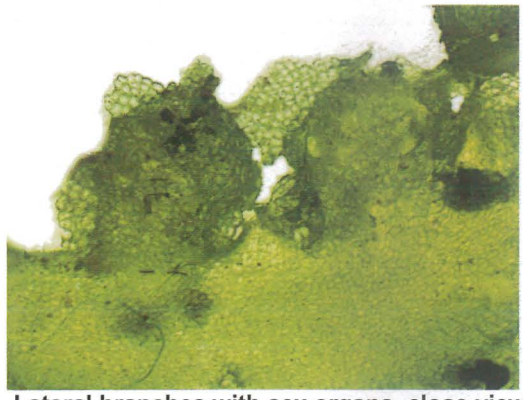
Whole mount of plants (scale 1.0 mm)



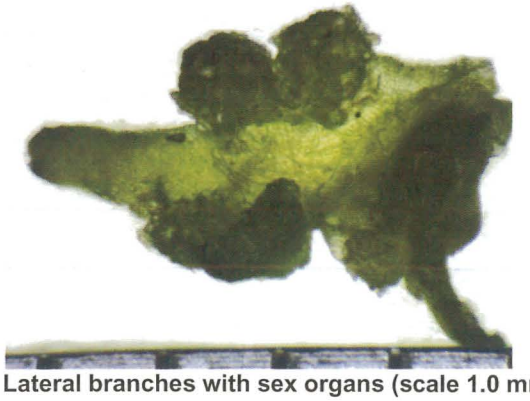
Whole mount, close view



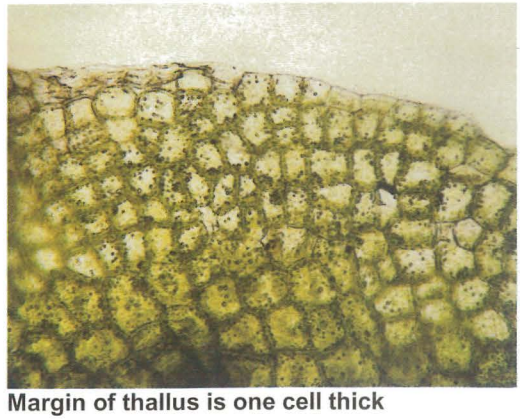
Lateral branches with sex organs (scale 1.0 mm)



Lateral branches with sex organs, close view



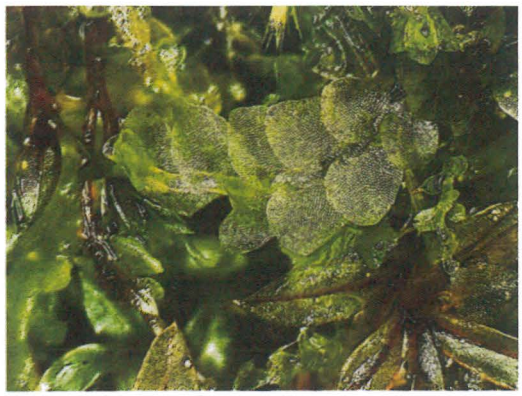
Lateral branches with sex organs (scale 1.0 mm)



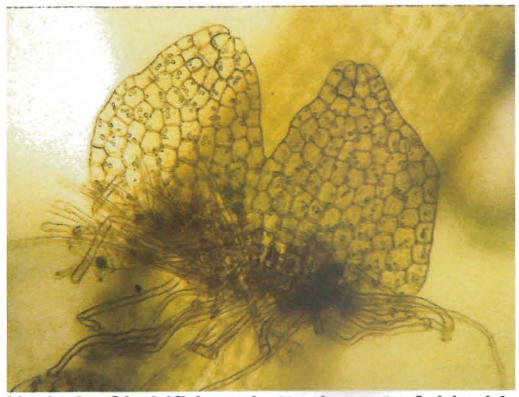
Margin of thallus is one cell thick

Plate 2

Calypogeia muelleriana

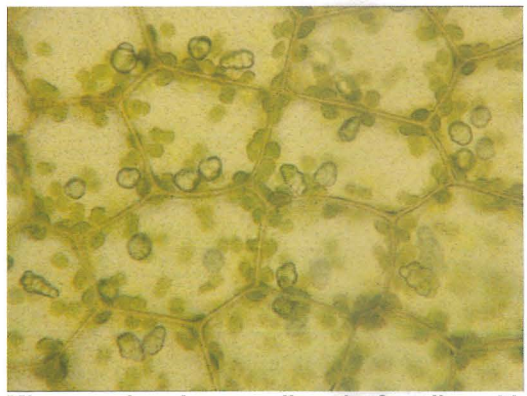


Whole plant in life is pale green

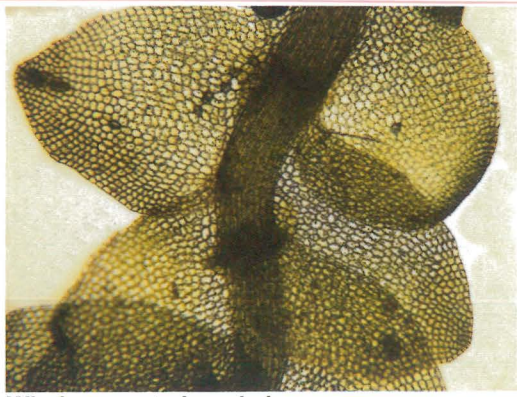


Underleaf is bifid, and attachment of rhizoids on stem at base is a transverse rectangular area.

Live plant close up, dorsal view. Leaves are incubous.



Microscopic view median leaf cells with mostly two oil bodies per cell.



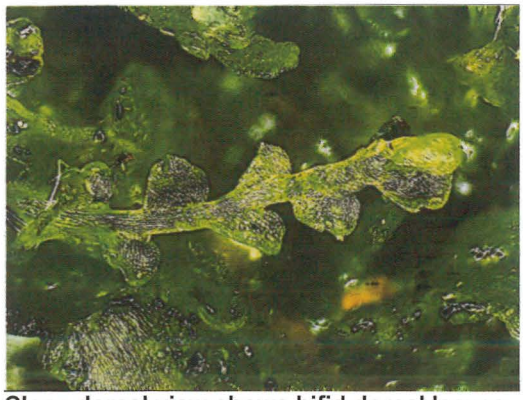
Whole mount, dorsal view.

Plate 3

Cephalozia pleniceps

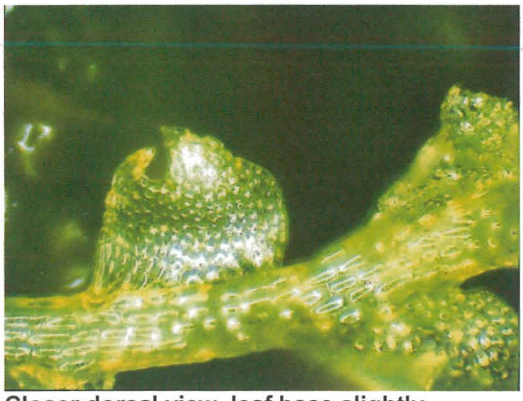
Whole plants.

Microscopic whole mount, leaves slightly decurrent.



Close dorsal view shows bifid dorsal leaves, Well spaced, succubous.

Dorsal view, leaves concave above.



Closer dorsal view, leaf base slightly decurrent.

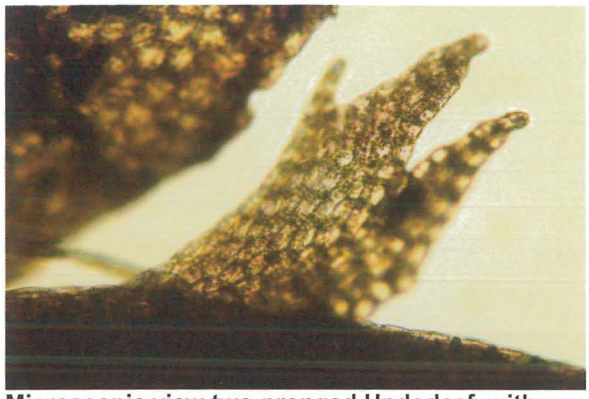
Lateral view, leaves concave

Plate 4

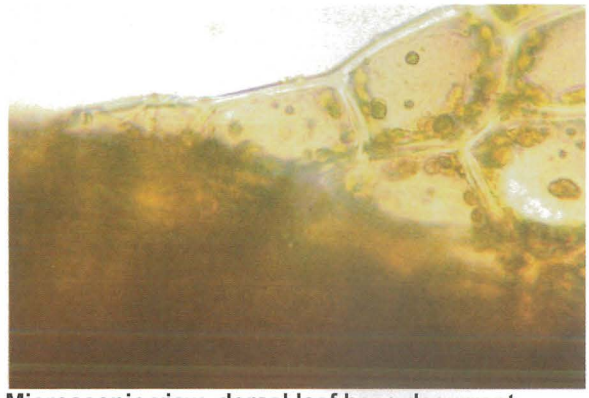
Chiloscyphus polyanthos

Living plants often pale green, succubous

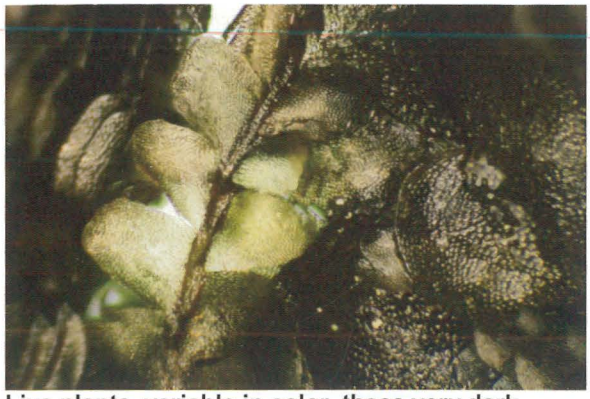
Microscopic whole mount, leaf apex truncate to indented (emarginate).



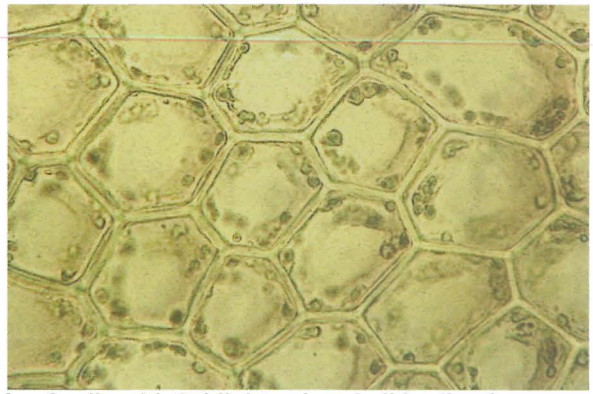
Microscopic view two-pronged Underleaf, with smaller tooth on each side.



Microscopic view, dorsal leaf base decurrent.



Live plants, variable in color, these very dark.



Leaf cells with 2-4 light colored oil bodies (green bodies are chloroplasts).

Cephalozia pleniceps (Austin) Lindberg [Cephaloziaceae] See **Plate 3**

(Main reference: Doyle & Stotler 2006 [p 144])
(Additional illustrations: Schofield 2002 [see similar *C. bicuspidata* p 76]; Smith 1990 [fig 22 p 57])

Leafy liverworts ranging in elevation from 1,400 to 3,300 m. Found in Europe, Asia, and North America, on damp, peaty soil near margins of marshy and boggy areas, less often on shaded rocks and decaying logs. Plants bright green; leaves succubous, bifid (split into two lobes), the pointed lobe apices are inflexed, but not touching each other. Leaves nearly semi-circular and conspicuously concave, obliquely inserted, not or only slightly decurrent (leaf margins at base extend down the stem in wing-like fashion) on dorsal stem surface. Underleaves absent. Stolons (flagelliform, or whip-like branches) frequently present. Perianth mouth crenate-dentate (scalloped-toothed).

Chiloscyphus polyanthos (L.) Corda [Geocalycaceae] See **Plate 4**
(Main reference: Doyle & Stotler 2006 [p 149]) (Additional illustrations: Frey *et al*. 2006 [fig 38 p 109]; Schofield 2002 [p 82]; Smith 1990 [fig 91 p 213]; Watson 1981 [figs 244 p 473]; Vitt *et al*. 1988 [p 154 (male plants])

A leafy liverwort ranging in elevation from near sea level to over 3,000 m. Found in Europe, Asia, Africa, and North America. Common on wet ground, shaded rocks, soil, organic debris and decaying logs, seasonally inundated or permanently submerged. They form loose, prostrate mats, pale or dull green to brownish in color, with stems 2-4 cm long. The obliquely set dorsal leaves are succubous. The leaf apices are rounded, truncate (abruptly cut-off), or slightly emarginate (indented). On the bottom side of the stem is a single row of small underleaves that are much different from the dorsal leaves. These are two-pronged, and usually have an additional smaller tooth on one or both sides. Two Californian species of this genus are polymorphic and occasionally difficult to separate. The distinction is on the basis of size of leaf cells, the number of oil bodies in the median leaf cells, and characters of the lobes of the perianth mouth. Unfortunately, most collections are vegetative, so the only reliable macroscopic character is the perianth mouth lobes; entire or with short teeth for *C. polyanthos*, clearly lobed to spinose for *C. pallescens* (Ehrh. Ex Hoffm.). Dumortier is usually not available. Whenever possible, examine fresh plants under the microscope to determine the number of light colored oil bodies in the median leaf cells. *Chiloscyphus polyanthos* has 2-4, whereas, *C. pallescens* has 4-8 (or more) oil bodies per cell. All fresh materials examined during this study were referable to *C. polyanthos*.

Marchantia polymorpha Linnaeus [Marchantiaceae] See **Plate 5**

(Main reference: Doyle & Stotler 2006 [p107])
(Additional illustrations: Frey *et al.* 2006 [fig 5 p 18]; Schofield 2002 [p 144]; Smith 1990 [fig 140 p 320]; Watson 1981 [figs 201-203 pp 413-415]; Vitt *et al.* 1988 [p 154 (male plants])

This complex thalloid liverwort is cosmopolitan in distribution, occurring as a garden and greenhouse weed, and at moist sites such as banks of streams, seeps, springs, and fens, from sea level to elevations over 3,600 m. The large flat surface of the thallus is up to 5 cm long and 2 cm wide and has a distinctive hexagonal patterning (visible with the naked eye) due to the large air chambers in the thallus. Each air chamber has a small pore. Sexes are on separate plants (dioicous), and the photo herein shows the female plants bearing structures called archegoniophores or carpophores that occur as umbrella-shaped structures with finger-like rays on the end of long stalks. The male plants have similar stalked structures with a rounded disk-like terminus. These structures are not often seen, but the species is *usually* otherwise easily recognizable by the presence of small cup-shaped structures (gemma receptacles) that bear small, green, lens-shaped asexual reproductive bodies called gemmae. In addition, the thallus often has a darkened central band of cells along its length: a feature not seen in other local genera resembling *Marchantia*.

Riccardia multifida (L.) Gray [Aneuraceae] See **Plate 6**

(Main reference: Doyle & Stotler 2006 [p 132])
(Additional illustrations: Frey *et al.* 2006 [fig 15 p 46]; Schofield 2002 [see similar *R. latifrons* p 186]; Smith 1990 [fig 132 p 301]; Watson 1981 [fig 209 pp 423])

A green to brownish-green simple thalloid liverwort occurring in shaded, wet areas, decaying logs and organic matter, and on wet rocks and soil of stream banks. Elevations range from sea level to 1,700 m. Found in Europe, Asia, North Africa, New Zealand, and North America. Both sexes occur on the same plant (autoicous). The thalli are 1-3 times pinnately (like a feather) branched. The branches are narrow, 1-3 mm wide, without a midrib, often crowded and mostly narrowed toward the tip. The margins of the branches are unistratose (only one cell thick) for a width of 2-4 cells, giving the branches a translucent appearance when wet (blackish when dry). *Riccardia multifida* is most likely to be confused with *Aneura pinguis*, or *Pellia* sp., but unlikely to be confused with any hornwort (see discussion for *Aneura pinguis*). Although Doyle (2006) does not report *R. multifida* in California above 1,700 m elevation, the material examined here found at 2,200 m was distinguished from the similar *R. chamedryfolia* (With.) Grolle that occurs to 2,300 m elevation, by the unistratose thallus margins 2-4 cells wide, and absence of oil bodies from the marginal cells (note: oil bodies must be observed using a microscope in fresh material; they are lost on dried specimens). Plants observed to be irregularly or palmately (in the fashion of fingers on a hand, or palm) branched are referable to two other species of *Riccardia*.

Scapania undulata (L.) Dumort. var. ***undulata*** [Scapaniaceae] See **Plate 7**

(Main reference: Doyle & Stotler 2006 [p 184])
(Additional illustrations: Schofield 2002 [see similar *S. bolanderi* p 196]; Smith 1990 [fig 79 p 190]; Watson 1981 [fig 253 pp 486])

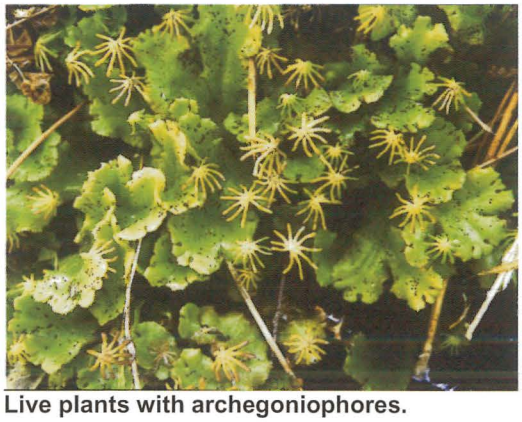
A leafy liverwort occurring in a wide range of habitats from submerged or near water-level of flowing water and cascades, to exposed summer-dry exposures, on sandy and gravelly soil, on rocks, boulders, and wood. Elevation ranges from near sea level to 3,300 m. Found in Europe, Asia, North Africa, New Zealand, and North America. This is the only leafy liverwort treated here that has leaves that are complicate-bilobed (folded over each other, like a taco shell), and the margins of the lobes are dentate (toothed). The dorsal leaf lobe is clearly smaller than the rounded ventral lobe. The ventral leaf lobe is long decurrent. Plants are remarkably variable in size, shape and coloration. Leaves are green in shade forms, reddish-purple in the sun, and have sometimes smooth, but usually dentate margins. Plants are up to 5 mm wide and 20 cm long, often forming large mats. Similar, but whitish to pale green plants with dorsal and ventral lobes nearly the same size may be referable to *S. subalpina* (Nees) Dumort.

Plate 5

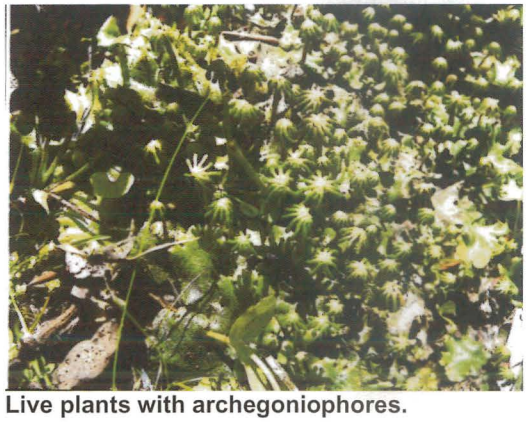
Marchantia polymorpha

Live plants with cup-shaped gemma receptacles.

Close view cup-shaped gemma receptacles, air chambers and pores.

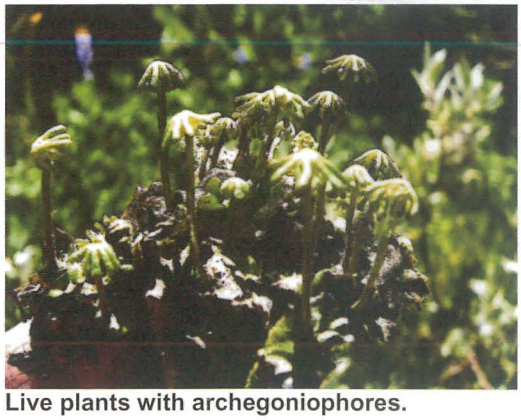


Live plants with archegoniophores.



Live plants with archegoniophores.

Close view of archegoniophores.



Live plants with archegoniophores.

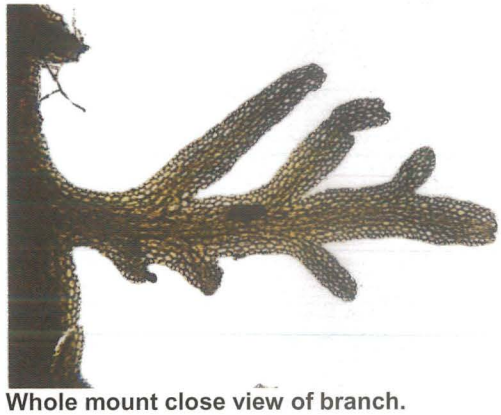
Plate 6

Riccardia multifida

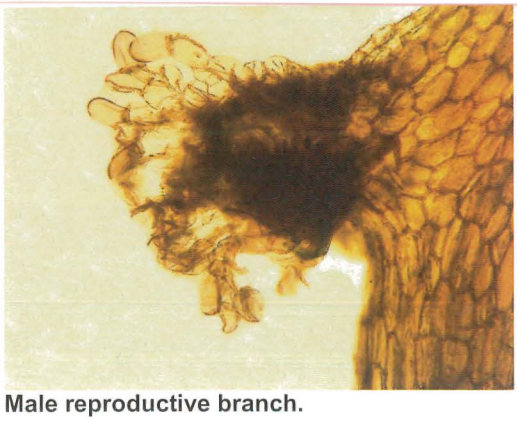
Live plants.

With developing sporophyte with black capsule and translucent seta.

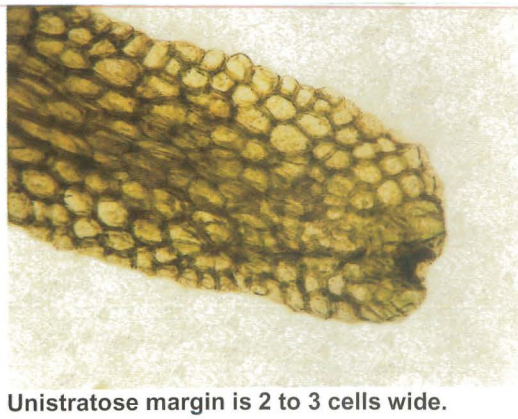
Live whole mount shows 2-pinnate branching.



Whole mount close view of branch.



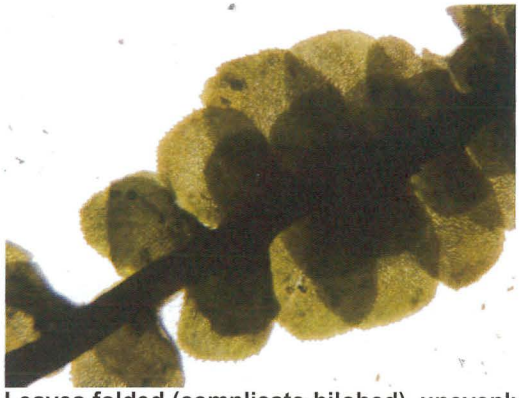
Male reproductive branch.



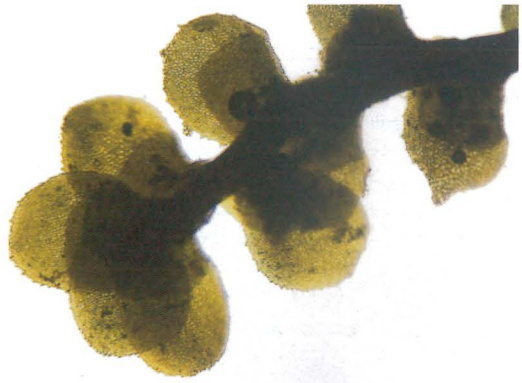
Unistratose margin is 2 to 3 cells wide.

Plate 7

Scapania undulata var. *undulata*



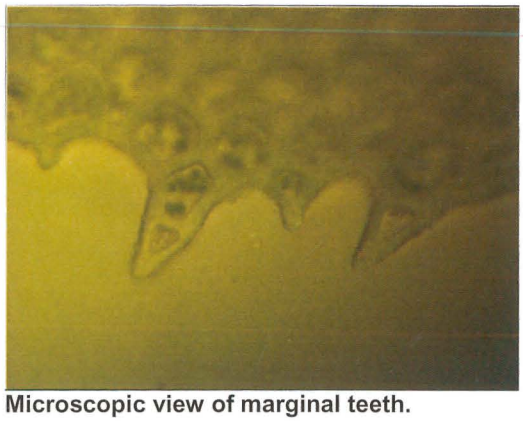
Leaves folded (complicate-bilobed), unevenly, upper lobe smaller.



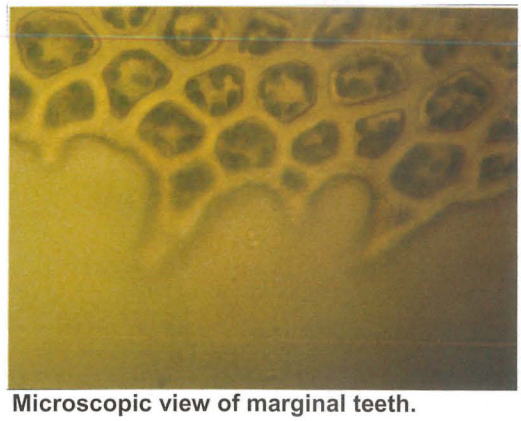
Stem apex, dorsal view.

Close view of bilobed leaves.

Serrate leaf margin.



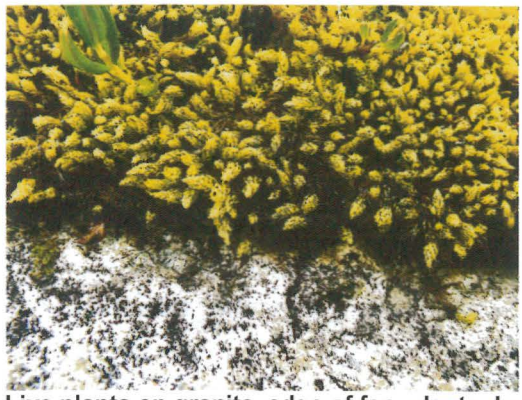
Microscopic view of marginal teeth.



Microscopic view of marginal teeth.

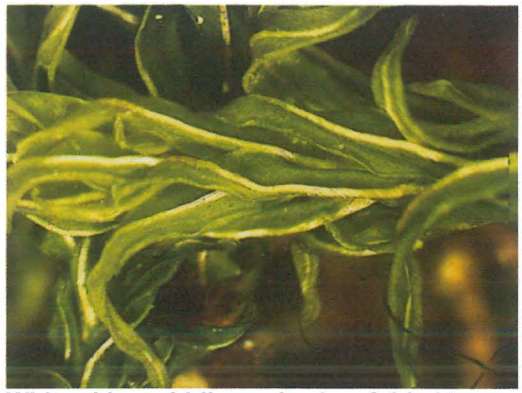
Plate 8

Aulacomnium palustre

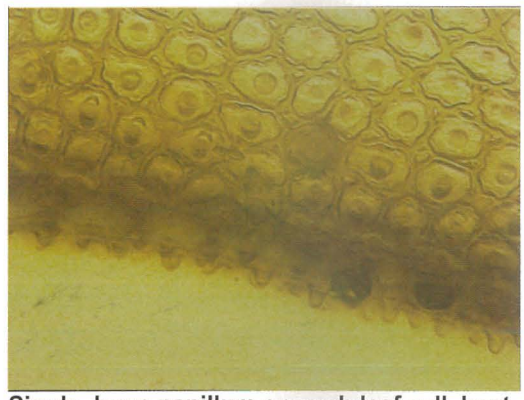


Live plants on granite, edge of fen, plants dry.

Plants with young gemmaphores.

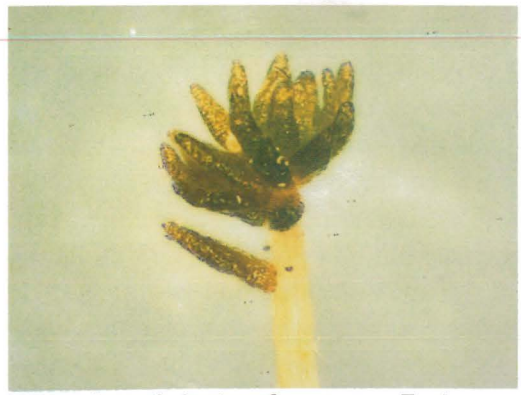


White shiny midribs on backs of dried leaves.



Single, large papillum on each leaf cell, best seen along curved leaf margin of dry specimen.

Gemmaphore has leaves extending from base, Cluster of gemmae at apex.



Close view of cluster of gemmae. Each gemmum Is 0.3 mm long.

Key to Acrocarpous Mosses

1 Plants *very* small, 2-3 mm tall, appearing somewhat like a soft, green felt. Leaves are subulate (long and slender, needle or awl like); occurring on drying banks of streams cut through meadows and moist soil; capsules maturing in summer to late fall, orange at first, with distinctive widening of the stalk (seta) below the capsule, eventually becoming purplish, and laying flat on the ground, indehiscent ..... ***Bruchia bolanderi***

1' Plant substantially larger, leaves not subulate..... **2**

2 Plants very pale whitish, greenish, yellowish, brownish, or reddish, with capitulae (head like clusters) at stem apices; branches below apex arranged in clusters or fascicles along the main stem, with some diverging, and some pendant, pointing downward parallel to the stem; leaves *without a costa* (midrib), of two kinds, those on branches mostly ovate to ovate-lanceolate, concave, and those on main stem triangular to lingulate (tongue-like), obscured by the branches..... ***Sphagnum*** spp.

2' Plants without this combination of characters; capitulae and fascicled branches absent: costa mostly evident..... **3**

3 Plants pale green to yellowish, erect, often with gemmaphores (extension of the main stem above the leaves bearing a cluster of tiny asexual gemmae); leaves ovate to lanceolate (lance shaped, narrow and tapering from the base), without a differentiated border on the margin; costa on the back of dry leaves very white, shiny, sinuous; leaves with very minute papillae (bumps) on the upper surface and these appearing as tiny teeth on the margins..... ***Aulacomnium palustre***

3' Plants green or pale green, but without a *white* shiny costa on back of dried leaves, and without gemmae on an elevated stalk above the leaves..... **4**

4 Plants green, with leaves distinctly arranged in three rows as a long spiral along the stem; leaves with sharp apices and serrate (saw-toothed) margins; leaves strongly squarrose (spreading at right angles from the stem) when wet, twisted and contorted when dry ..... ***Meesia triquetra***

4' Not as above; leaves not in three rows on the stem **5**

5 Leaves *without* a marginal border of elongate cells (observe the leaves using transmitted light to see if the border is differentiated, or not) **6**

5' Leaves with a marginal border of elongate cells **7**

6 Leaf margins entire (smooth, without teeth), and with a blunt, rounded to obtuse apex, and costa ending just short of the apex, costa wide, occupying ½ the width of the leaf base ..... ***Meesia uliginosa***

6' Leaves minutely toothed, ovate-lanceolate to long lanceolate, with a strong costa extending at the apex or extending well beyond as a long tip; stems red; plants often yellowish-green; some plants may show distinctive whorls of branches near the apex of the stem; rosette like perigonia (clusters of antheridia) common on some stem apices; capsules when present rather rounded in shape, shriveling like dried apples..... ***Philonotis fontana***

7 Large plants with large, glossy green, rounded to ellipsoid leaves, with single sharp teeth spaced along the strongly bordered leaf margin; erect stems curving outward, and leaves arranged rather two-ranked..... ***Plagiomnium medium***

7' Leaves without strong marginal teeth..... **8**

8 Leaves large, mostly 3-4 mm long, closely spaced on the red stem, not decurrent ..... ***Ptychostomum* 'pacificum' (undescribed)**

8' Leaves usually smaller than 3 mm, well spaced on the red stem, especially in the middle portion of the stem, and *strongly* decurrent..... ***Ptychostomum pseudotriquetrum***

Descriptions of Acrocarpous Mosses

Aulacomnium palustre (Hedwig) Schwaegrichen [Aualcomniaceae] See **Plate 8**

(Main reference: Lawton 1971 [p 202]; Smith 2004 [p 637])
(Additional illustrations: Crum & Anderson 1981 [fig 291 p 620]; Flowers 1973 [pl 65 p 319]; Frey *et al.* 2006 [fig 91 p 280); Lawton 1971 [pl 111]; Malcolm *et al.* 2009 [p 220]; Schofield 1992 [p 71]; Sharp *et al.* 1994 [fig 406 p 538]; Smith 1978, 2004 [fig 211 p 637]; Vitt *et al.* 1988 [p 78]; Watson 1981 [fig 117 p 294])

A common and abundant circumpolar, boreal, and montane species found on wet soil and within peat. It is known to grow up onto wood and rocks at fen margins. Found in North America, New Zealand, Australia, and Tasmania. This species often has gemmaphores, also called pseudopodia (erect continuations of the main stem with terminal, globose clusters of elliptical gemmae). They form yellowish-green turfs. Stems are covered with a dense, rust-colored tomentum comprised of rhizoids. This, together with the strongly papillose (tiny bumps) leaf cells, and *pearly-white*, and sinuose costa on the *dried* leaves are good field characters. Use a hand lens to examine the recurved (curved backwards) margins of the leaves to see these minute bumps. The dark green gemmae (up to 0.3 mm long) are elliptic, curved upward, and divergent from the whitish apex of the gemmaphore. Gemmae are often missing, leaving only the naked gemmaphore. The gemmaphore can be distinguished from the seta of a sporophyte, because leaves extend along its lower portion; not a characteristic of a seta, which arises from a terminal cluster of leaves enclosing the female gametangia (archegonia), the cluster being called a perichaetium. The leaves of a perichaetium do not spread out along a stem in this fashion.

Bruchia bolanderi Lesquereux [Bruchiaceae] See **Plate 9**

(Main reference: Zander 2007)
(Additional illustrations: Malcolm *et al.* 2009 [p 95]; Zander 2007 p 431)

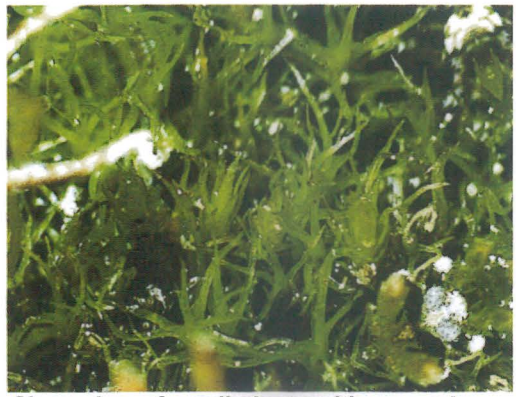
A tiny moss, only about 2-3 mm high, with narrowly subulate (long-tipped) leaves. Considered rare,[3] endemic to western North America, occurring as a summer-growing ephemeral from montane to alpine zones in Oregon and California. The plants often form bright green turfs

[3] It remains on both California's list of Special Bryophytes (California Department of Fish and Game (2009), and on the Region 5 list of Special Concern, following a recent meeting (2010) of the California Bryologists Working Group.

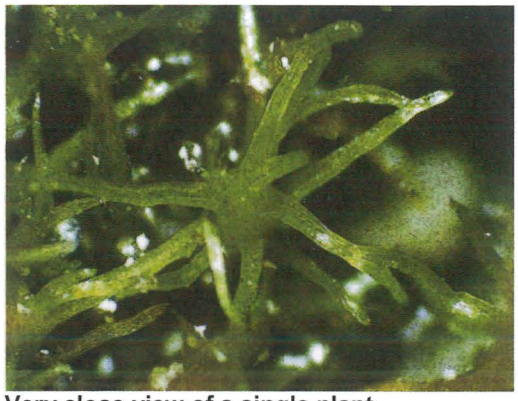
Plate 9

Bruchia bolanderi

Tiny mosses 2-3 mm high look like fine green felt.



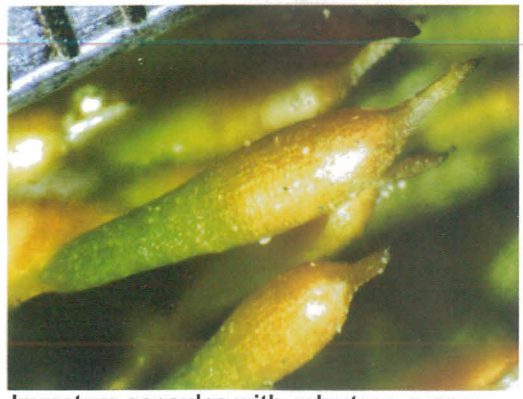
Close view of small plants with narrowly subulate leaves.



Very close view of a single plant.

Immature orange colored capsules appear in late summer.

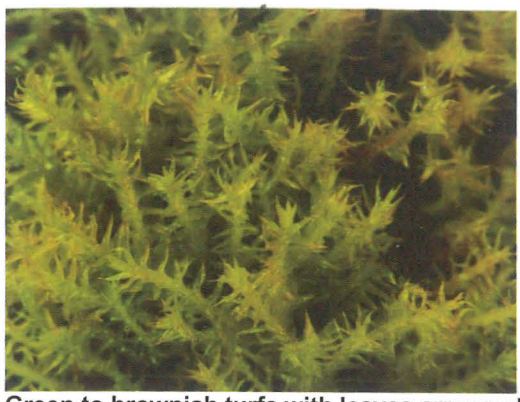
Capsules mature in late fall, darkening and laying flat. They don't open.



Immature capsules with calyptrae, orange spore sac, and green hypophysis below.

Plate 10

Meesia triquetra

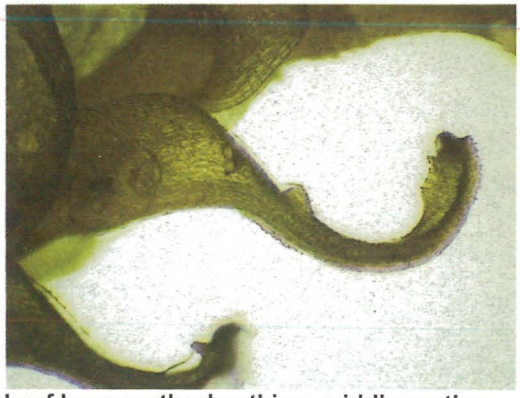


Green to brownish turfs with leaves arranged in three ranks on the stem.

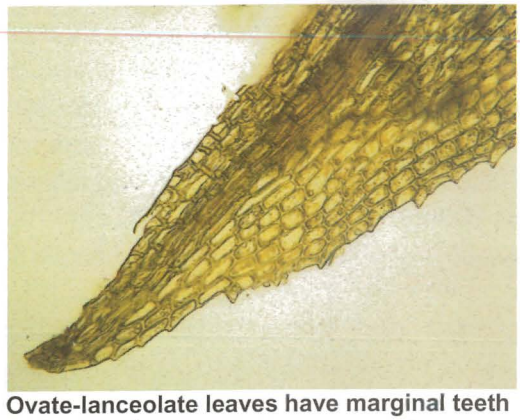
The leaves become very crisp and contorted when dry.

Close view of several plants with wide spreading leaves.

Very close view of stem apices and wide spreading leaves in three ranks.



Leaf base partly sheathing, middle portion spreading, tip curved upward in "S" shape.



Ovate-lanceolate leaves have marginal teeth and an acute apex.

on disturbed mineral and organic soils, often at the drying upper margin of stream channels that have been cut through moist meadows, along rivulets, fens, and springs. It is easily overlooked without sporophytes. However, it can be recognized by the green turfs that resemble algae or a soft green felt of tiny plants with their subulate leaves. Plants without sporophytes resemble the genus *Ditrichum*, but none of these grow in the montane zone and above. Also, the plants have very persistent protonemata, the green filamentous growth from germination of the spores, resembling algae. Thus, this species can be reliably determined without sporophytes. When present, the sporophytes are very distinctive, with an elongate swollen neck (hypophysis) equaling the length of the capsule itself. These appear late in the summer, around mid-August, or later. Initially, the sporophytes are very orange in color, and stand upright. As the sporophytes mature in late fall the color becomes purple and they lay flat. Sporophytes do no open to release spores until the spring, after the capsule wall decays. The capsules are cleistocarpous (not opening by a lid).

Meesia triquetra Jolyclerc (Ångström) [Meesiaceae] See **Plate 10**

(Main reference: Vitt 2007)
(Additional illustrations: Crum & Anderson 1981 [fig 298 p 631]; Frey *et al.* 2006 [fig 91 p 280]; Lawton 1971 [pl 112]; Malcolm *et al.* 2009 [p 163]; Schofield 1992 [p 192]; Smith 1978, 2004 [fig 170 p 522]; Vitt *et al.* 1988 [p 82])

This moss occurs in rich fens in arctic and boreal regions of North America and Eurasia, disjunct in a few locations further south, including California, where it is uncommon[4], but when it occurs, it can be locally abundant. This species is very easy to recognize because of several distinctive features. The ovate-lanceolate leaves are wide-spreading from a somewhat sheathing base, appearing nearly squarrose (spreading at right angles from the stem), and the tips of the leaves turn upward from the spreading mid-portion of the leaf, giving the whole leaf a distinct "S"-shape, especially when moist. When dry, the leaves are rather contorted. The most distinctive feature of this moss is that the leaves are attached in three-ranks (moist) when viewed from above, appearing as a long spiral down the stem. The dark green leaves have serrulate (finely toothed) margins that are reflexed below, and decurrent on the stem. The costa is strong, ending at or just below the acute apex. A related species with leaves in three ranks is *Meesia longiseta* Hedwig, which has entire leaves, and is more likely to have sporophytes, being autoicous. In *Meesia triquetra*, sexes are separate (dioicous), and when present, the asymmetrical capsules have long necks, or hypophyses, that abruptly expand into the spore sac. The seta (stalk of the capsule) is exceptionally long, as much as 10 cm.

[4] It remains on California's list of Special Bryophytes (California Department of Fish and Game (2009). It was suggested for removal from the R-5 FS Regional Forester's 2006 Sensitive Plant Species list at a meeting (2010) of the California Bryologists Working Group.

Meesia uliginosa Hedwig [Meesiaceae] See **Plate 11**

(Main reference: Vitt 2007)
(Additional illustrations: Crum & Anderson 1981 [fig 295 p 627]; Frey *et al.* 2006 [fig 91 p 280]; Lawton 1971 [pl 112]; Malcolm *et al.* 2009 [p 162]; Smith 1978, 2004 [fig 170 p 522]; Vitt *et al.* 1988 [p 82])

This is a species of rich fens, moist calcareous banks, and soil covered rock crevices, ranging through boreal and arctic Eurasia, and North America, extending south to Colorado and California, where it is rare[5]. This author frequently observes that it occurs slightly above the level of saturation in a fen, especially within and around raised hummocks of small shrubs, such as western blueberry, *Vaccinium uliginosum*. Unlike *Meesia triquetra* (and *M. longiseta*), the leaves are not three-ranked, either when moist or dry. Also, the leaves are not wide spreading or squarrose. Instead, the leaves are more erect, and are lingulate (tongue-shaped), rather than ovate-lanceolate. The leaf apex is typically rather rounded, but some leaves with bluntly acute apices are observed by this author. The leaf margins are entire, with clearly revolute (tightly rolled backward, downward) margins. The very wide leaf costa occupying 1/2-2/3 of the width of the leaf base ends in a distinctive manner just below the *blunt* leaf apex. Sexes are usually separate (dioicous), but when present, the sporophytes have a very long seta, and asymmetrical capsules have long necks (hypophysis) that abruptly expand into the spore sac. As with the other *Meesia*, the seta is rather long, up to 10 cm. Capsules are very rare in California.

Philonotis fontana (Hedwig) Bridel [Bartramiaceae] See **Plate 12**

(Main reference: Griffin 2003)
(Additional illustrations: Crum & Anderson 1981 [figs 310, 311 pp 654-655]; Flowers 1973 [pl 68 p 330; pl 69 p 331]; Frey *et al.* 2006 [fig 90 p 277]; Lawton 1971 [pl 116]; Malcolm *et al.* 2009 [p 351 leaf outline only; (as *P. americana*) p 199; (as *P. tomentella*) p 387 leaf outline only)]; Schofield 1992 [p 209]; Smith 1978, 2004 [fig 215 p 652]; Vitt *et al.* 1988 [p 81]; Watson 1981 [fig 120 p 298])

Nine species of this genus are reported from the Cascade Ranges and Sierra Nevada of California (Norris & Shevock 2004), growing on moist soil of seepages, or in bogs and fens. However, some of these are currently not recognized, or they are considered varieties of *P. fontana* by Griffin (2003). They are often the dominant species in our fens. They have striking colors from pale green, yellow-green, golden through orange, bronze, brown, and reddish. The ovate-lanceolate to long lanceolate leaves are arranged in very neat, slow spirals down the contrasting red stem. Our local material mostly shows leaves with *noticeably* long awns; an extension of the costa beyond the leaf blade. These erect plants often have some or many individuals with a characteristic whorl of terminal branches. Griffin calls these subfloral whorls. With or without these branches, the male gametangia, i.e., antheridia, are clustered

[5] It remains on the California Department of Fish and Game list of Special Bryophytes (2009), and on the R-5 FS Regional Forester's 2006 Sensitive Plant Species list, following a meeting (2010) of the California Bryologists Working Group.

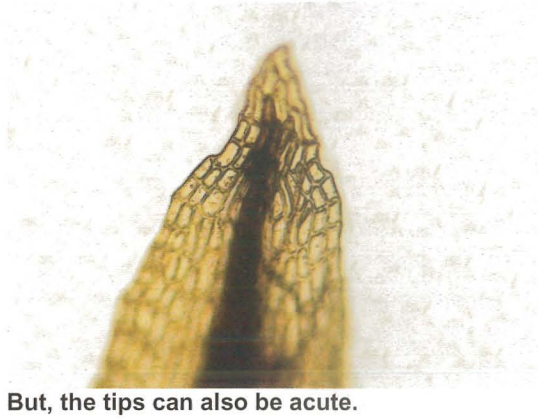
Plate 11

Meesia uliginosa

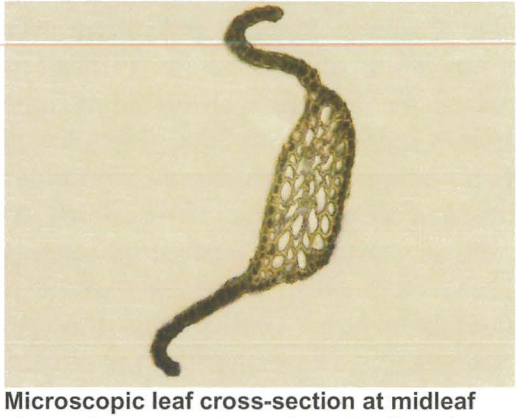
Living plants form dense turfs raised slightly above the saturated level of the fen.

Color varies from dark green to red, becoming white when encrusted with calcium (right).

Leaves have blunt apices, entire margins, and a wide costa ending just before the apex.



But, the tips can also be acute.

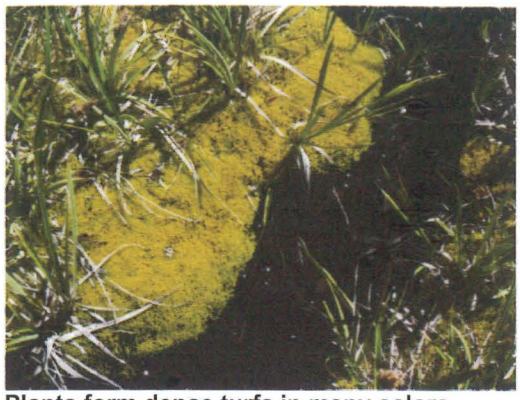


Microscopic leaf cross-section at midleaf shows the very wide costa and reflexed margins.

Costa at the base is half the width of the leaf.

Plate 12

Philonotis fontana



Plants form dense turfs in many colors - green, yellow, golden, to bronze and reddish.

Lanceolate leaves neatly arranged on red stems.

Sporophytes are uncommon, unusually plump, and globose.

A rare profusion of brightly colored maturing capsules.

Minute, well spaced marginal teeth and a long excurrent costa are characteristic.

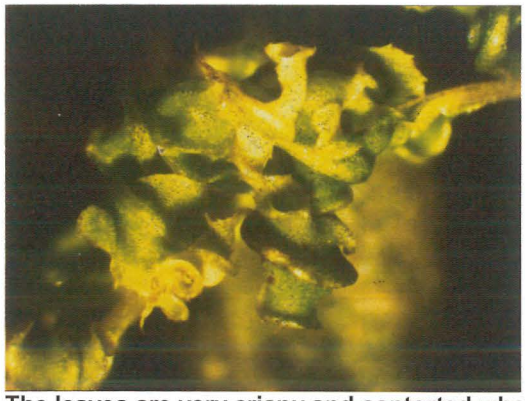
Reproductive whorl of branches; and perigonia.

Plate 13

Plagiomnium medium

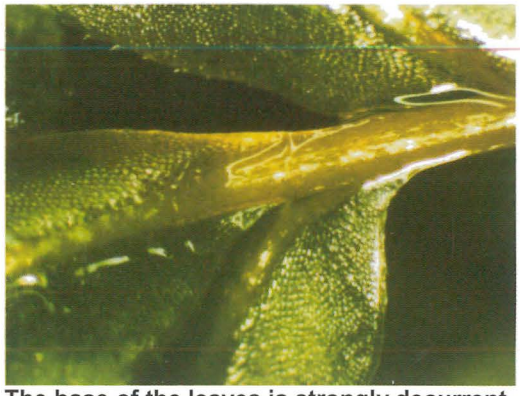
Live plants grow in shaded areas, robust, with outward curving branches.

When wet, the leaves on sterile stems tend to arrange in two-ranks.

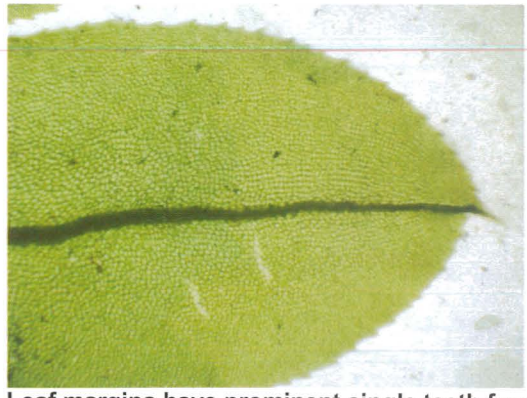


The leaves are very crispy and contorted when dry.

Leaf shape varies; lanceolate perichaetial, to elliptic and suborbicular.



The base of the leaves is strongly decurrent
Note: marginal teeth to near base.

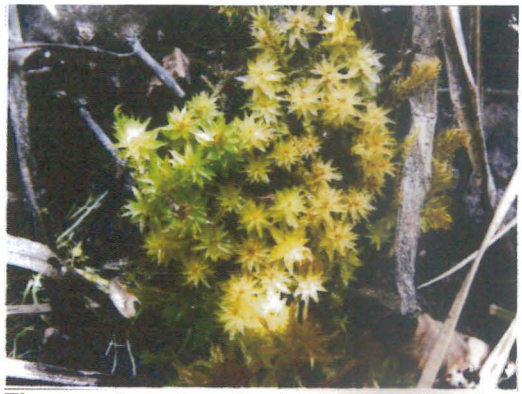


Leaf margins have prominent single teeth from apex to nearly the base.

Plate 14

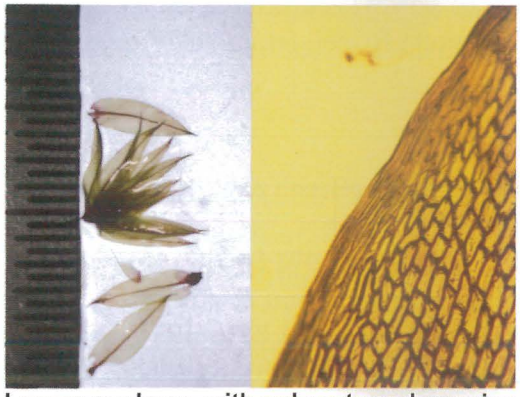
Ptychostomum pacificum

Very robust plants with large leaves form thick turfs.



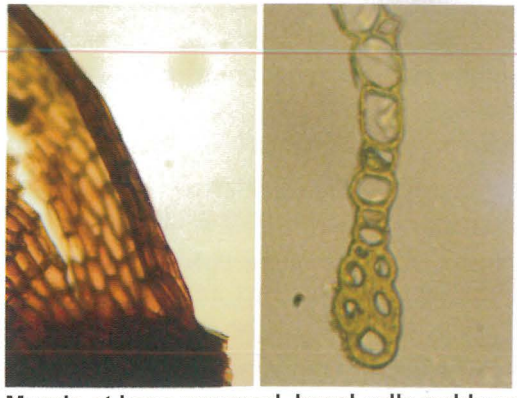
They can be pale yellowish to green in color.

The leaves are closely spaced on red stems.



Leaves are large, with red costa and margins. Scale 0.5 mm. Close view of margin of elongate cells.

Ovate-lanceolate leaves have strong costa And border on margin, often with reddish coloration.



Margin at base recurved, basal cells reddened. Microscopic cross-section bistratose margin.

together in very distinctive, rosette-like apices termed perigonia. Each perigonium is a head comprised of many antheridia, looking much like an open sunflower or thistle. The perigonial leaves are very shortened and ovate, compared to the stem leaves below that tend toward lanceolate shape. Leaf cells are covered with small bumps; called prorae or prorations that form as an extension of the cell walls at the lower, or proximal ends of the cells. These can be seen with a hand lens along the leaf margins, especially on dry leaves viewed under transmitted light, because they glisten. The teeth are well spaced, and seeming to point outward at right angles to the margin, looking like little glass beads in the sunlight. The *fontana* complex notably has these unusual marginal teeth that sometimes appear to be formed from the extended ends of two adjacent cells. As with many other genera of fen habitats, *Philonotis* species have a dense coating of red-brown rhizoids on the lower portions of the stems. The stems are strongly red, in contrast to the leaves. Plants are usually dioicous (separate sexes). Therefore, sexual reproduction, and the resulting unusual globose capsules are not often seen. They start out a delicate purplish, maturing to yellow and brown, and age to resemble dried apples.

Most of the material examined during this study were "small" plants, with stiffly erect, narrowly lanccolate to ovate-lanceolate leaves, and these with a long costa extending as an awn beyond the leaf apex, Also the leaves are not plicate (lengthwise pleated, furrowed or wrinkled), and with their apices not twisted around the stem. As such, they are referable to *Philonotis fontana* var. *pumila* (Turner) Bridel, treated as *P. tomentella* Molendo in Lorentz by Norris and Shevock (2004a, b).

Plagiomnium medium (Bruch & W.P. Schimper) Koponen [Mniaceae] See **Plate 13**

(Main reference: Lawton 1971 [p 197]; Flowers 1973 (as *Mnium medium*) [p 392])
(Additional illustrations: Crum & Anderson 1981 (as *Mnium medium*) [fig 278 p 597]; Flowers 1973 (as *Mnium medium*) [pl 87 p 393]; Lawton 1971 [pl 107]; Malcolm *et al.* 2009 [p 184]; Sharp *et al.* 1994 [fig 403 p 533]; Smith 1978, 2004 [fig 207 p 627]; Vitt *et al.* 1988 [p 74])

These are rather large plants with large, glossy, broadly ovate, rounded to elliptical leaves, with a strong border on the margin, and strong costa. They are circumpolar, boreal, and montane in distribution. Found in Europe, Asia, Greenland, and North America. In North America they are found in California, Nevada, Utah, Iowa, and Virginia. They grow primarily in shaded areas on wet ground, humus, rotten logs, and rocks; mostly along small streams, springs, and in seepy areas. Elevation range is from lowlands to 3,000 m. Leaf bases are strongly decurrent. The leaf margin has sharp *single* teeth *all the way to the base*, and a sharp point at the apex. Leaf cells are short hexagonal and rather large. *Rhizoids occur on the erect sexual stems all the way to the top*. The erect sterile stems have a characteristic long *curvature* toward the ground, with the leaves somewhat flattened into one plane. The leaves are very crisped and contorted when dry. Microscopic confirmation: plants are synoicous, that is, with both antheridia and archegonia in the same cluster at the apex of the fertile stems. Other similar species include *P. ellipticum*, and *P. rostratum* with leaves not decurrent; *P. insigne* without rhizoids all the way to the stem apex; *P. cuspidatum* with marginal teeth only on upper ½ of the leaf, and *P. venustum* with teeth very long and sharp. Related genera include *Rhizomnium*, without any teeth on the margin, and *Mnium*, with paired teeth on the margin.

***Ptychostomum* pacificum** [Bryaceae] See **Plate 14**

(Main reference: none)
(Additional illustrations: none)

A relatively common *Bryum* [sensu lato] of Sierran and southern Cascade fens in the segregate genus *Ptychostomum*. It is a robust species with large, translucent leaves, approximately 4 mm long, with a distinct thickened border, and strongly contorted leaves when dry. According to John Spence, an authority on these mosses, this undescribed species is "basically a giant form of *Bryum turbinatum*, but with an elongate capsule." The leaves are rather closely spaced on the middle portion of the stem, and the base of the leaves is *not* decurrent. (*P. pseudotriquetrum* (below) has well spaced leaves that are clearly decurrent). Capsules are rare, because the species is dioicous (male and female plants separate). Although it grows in full sun, it is also often found growing underneath the shade of vascular plant species in fens. Microscopic confirmation: leaf border is bistratose (two cells thick), comprised of thick-walled, elongate cells, unlike *P. pseudotriquetrum*, whose border is only one cell thick (one cell thick).

Ptychostomum pseudotriquetrum (Hedwig) J.R. Spence ex D.T. Holyoak & N. Pederson [<= *Bryum pseudotriquetrum* (Hedwig) Gaertner, Meyer & Scherbius)] [Bryaceae]
See **Plate 15**

(Main reference: Spence 2007; 2009)
(Additional illustrations: (mostly as *B. p.*) Crum & Anderson 1981 [fig 258 p 559]; Flowers 1973 [pl 79 p 370]; Lawton 1971 [pl 94]; (as *P. p.*) Malcolm *et al.* 2009 [p 172]; Sharp *et al.* 1994 [fig 359 p 477]; Smith 1978, 2004 [fig 184 p 565]; Vitt *et al.* 1988 [p 67]; Watson 1981 [fig 104 pp 275])

A widespread species of arctic, circumboreal and temperate regions, and including South America, Africa, New Zealand, and Australia, absent only from the subtropics and tropics. It grows abundantly throughout western North America on wet and peat soils. Found in fens, along streams, in seeps, and even in rock outcrops. It often has long stems densely matted with rhizoids. Leaves are ovate-lanceolate to oblong-lanceolate (widest above the middle), *widely spaced* with *long decurrent* (running down the stem) bases, and a short excurrent (leaf midrib extends just beyond tip of leaf) costa. Leaf margins are entire, bordered by several rows of thick walled linear cells, and are strongly revolute (rolled backwards at the edges) to midleaf, sometimes to the apex. Microscopic confirmation: leaf border is unistratose (one cell thick), comprised of thick-walled, elongate cells, unlike *P.* 'pacificum' whose border is bistratose.

Another species closely resembling *Ptychostomum pseudotriquetrum*, and occurring in fens is *P. weigelii* (Sprengel) J.R. Spence. It also has "strongly and broadly decurrent leaves." However, unlike *P. pseudotriquetrum*, it has "partially bistratose margin from base to mid-leaf." As such, it is actually more closely related to the previous *P.* 'pacificum,' in the subgenus *Ptychostomum*, and not in the subgenus *Cladodium*. *Ptychostomum pseudotriquetrum* also has "filiform gemmae sometimes present in the leaf axils" and *P. weigelii* does not. The distinctions on the basis of unistratose versus bistratose margin cannot be made in the field, however. This is a

rather a dilemma, and the present author cannot present any further reliable diagnostic field characteristics. However, all material examined in the course of this study with decurrent leaves exhibited unistratose margins, and was therefore referred to *P. pseudotriquetrum*.

Sphagnum Linnaeus [Sphagnaceae]
(Main references McQueen 1990; McQueen & Andrus 2007)

Sphagnum species are the true *peat mosses*. They are considered important indicators of climate change due to their tremendous biomass (global scale) and observed response to changing climate in their boreal habit, providing important implications concerning carbon and greenhouse gasses. *Sphagnum* species are placed in their own class, namely, Sphagnopsida. There is only one order – Sphagnales, one family – Sphagnaceae, and one genus – *Sphagnum,* in this highly successful and diverse class. They are not among the 'true mosses' of the order Bryales, having long since departed from the other mosses.

Branches are arranged in clusters, called fascicles, along the main stem; the young branches are usually crowded together at the top of the plant to form a head, or capitulum. As the stem elongates, the branches become obviously arranged in fascicles. They have two types of leaves – branch and stem leaves. Branch leaves (leaves on the branches) are arranged spirally, or sometimes 5-ranked, and closely overlap each other. Branch leaves are normally inrolled, such that the top surface is concave, widest in the lower one-fourth to one-third of the leaf *above* the base, and tapered to an inrolled apex. Stem Leaves (leaves on the main stem) are well spaced on the main stem, more or less flattened, often widest *at* the base, or in the middle or above, and are frequently lingulate (triangular to tongue-like) shaped. They usually cannot be seen until one or two whole, adjacent fascicles have been removed to expose the main stem. Stem leaves can be erect, pointing upward and appressed to the stem, but are more frequently reflexed backward and appressed to the stem. Presumably, they are bent backward as the main stem elongates near the capitulum. In any case, they will be difficult to see when the plants are saturated and covered by a film of water. Slight drying will help you to observe them, but completely dry plants are extremely brittle and easily broken.

Both stem and branch leaves are composed of a network of inflated, rhomboid to "S"-shaped, *dead* cells, which are colorless, or hyaline, and living green, chlorophyllose cells that are narrow and linear. Furthermore, the dead hyaline cells are perforated by pores, and commonly reinforced in the branch leaves by spiral fibrils, or thickenings in the cell walls. Fibrils are uncommon in the stem leaves. This network of dead cells with pores enables *Sphagnum* to retain up to 25 times their dry weight in water. Also, the preponderance of dead hyaline cells imparts a very pale gross appearance to the plants themselves, ranging from pale green, or with yellow, orange, brown, pink, red, and various combinations of these adding to the distinctive appearance of *Sphagnum*. Among other moss species encountered in fens, only *Helodium blandowii* might be mistaken for *Sphagnum*.

When examining these plants, pull off a few fascicles from near the middle of the main stem using your fingers or a forceps. Determine how many branches there are in the fascicles, how many are spreading outward (spreading branches), and how many are descending, or pointing

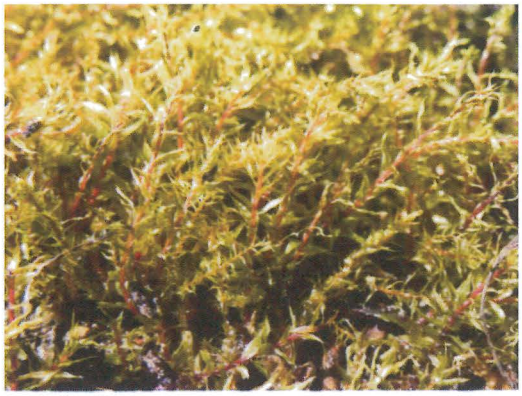
downward and closely appressed to the main stem (pendent branches). It may help to note if the leaves look different on the two types of branches. The spreading branches are often curved with the leaves more closely overlapping each other, whereas the pendent branches are straight, with leaves more widely spaced, sometimes smaller and narrower. The pendent branch may appear narrower and very long tapering compared to the spreading branches. You may need to examine the fascicles while still attached to the plant to determine how many are spreading and pendent. The plants will need to be moist, because the branches will easily break if the plant is completely dry, and this will make for errors in counting the branches. If the plant is saturated, the branches may adhere to each other (especially the pendent branches to the main stem) making their enumeration difficult.

Identification to species within the *Sphagnum* genera can be highly problematic. A dissecting scope (with magnifications above 20X), and a compound microscope (to examine whole and cross sections of leaves) are usually necessary. However, some experts contend that it is possible to make determinations of *Sphagnum* using macroscopic characters, and McQueen (1990) and Hill (1992) provide a field keys to many North American species.

In California, *Sphagnum* is restricted to perennially saturated soils of bogs and fens. The distribution of each species seems to be relictual, in that their distribution is strongly discontinuous. The taxonomy of Californian *Sphagnum* is not well understood, and their names can be expected to undergo substantial future revisions. Curious and unexplainable is the fact that no *Sphagnum* in California has ever been found with sporophytes. Norris and Shevock (2004a) report twenty-three species in California, and fifteen in the Sierra Nevada of California, but the recent comprehensive treatment of the genus in Flora of North America (McQueen & Andrus 2007) refutes the occurrence of five of these for California, and three for the Sierra Nevada. The majority of those cited for the Sierra Nevada are reported only from the central and southern portions of the range, from about Yosemite National Park southward. It is not known whether this is an artifact of under-collection, or a true representation. However, in the northern Sierra Nevada, the current study and other available data suggest that there are around five species, and only three of these are commonly encountered and recognized. This opens the possibility that a correct determination can be made using the information provided in this field guide, with caution. Not all of these species are pictured herein, however.

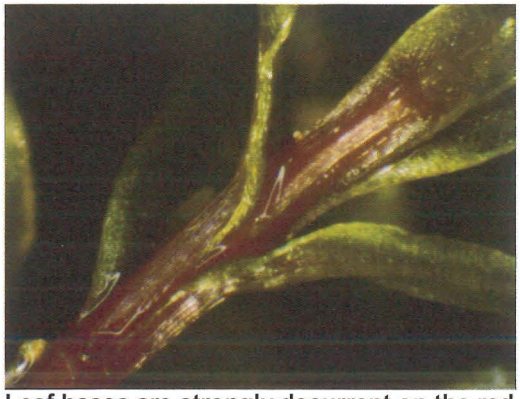
Plate 15

Ptychostomum pseudotriquetrum

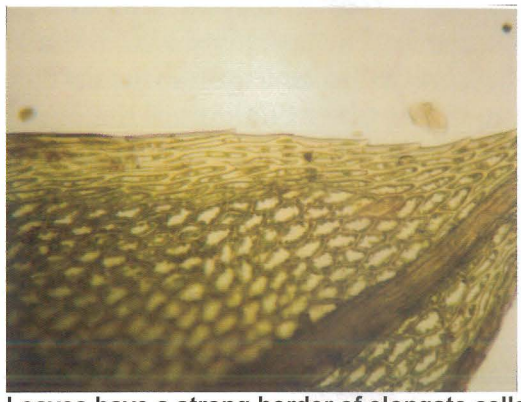


Living plants have well spaced leaves and red stems.

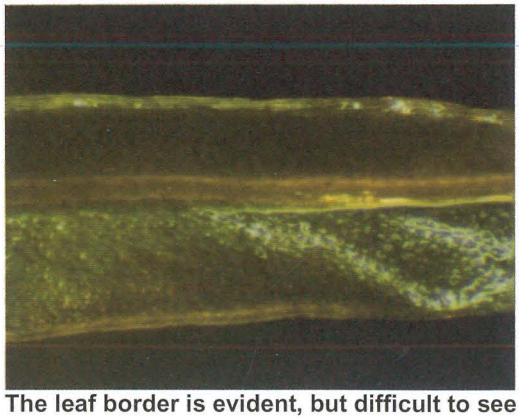
Closer view of hydrated plants.



Leaf bases are strongly decurrent on the red stems.



Leaves have a strong border of elongate cells on the margins in microscopic view.



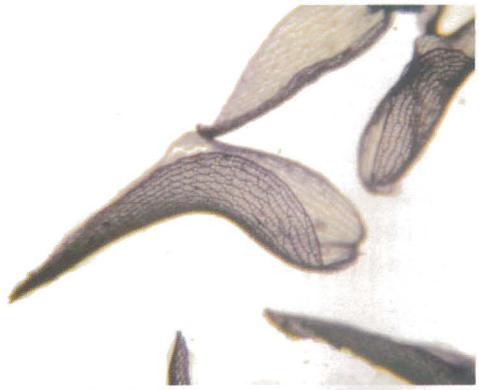
The leaf border is evident, but difficult to see at low power.

The leaf border is unistratose, and recurved to revolute.

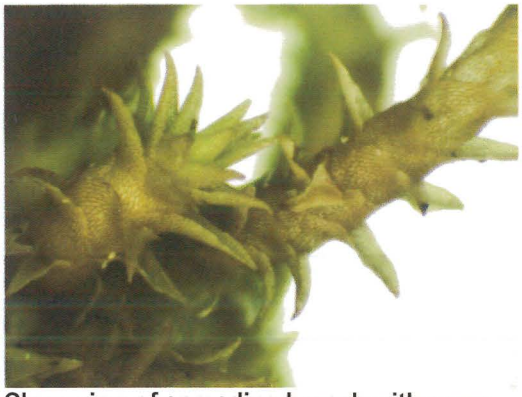
Plate 16

Sphagnum squarrosum

View of capitulum.



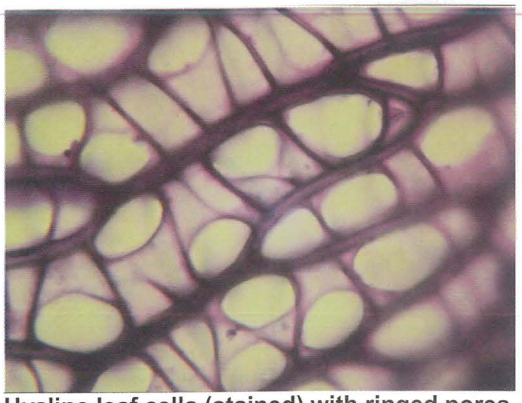
Microscopic view of squarrose stem leaf (stained).



Close view of spreading branch with some leaves strongly squarrose.

Microscopic view of lingulate stem leaves.

Fascicles (removed) mostly 2 spreading (curved) 2 pendent (longer tapered, straighter).



Hyaline leaf cells (stained) with ringed pores. Chlorocysts are linear, stained dark.

Key to *Sphagnum*

1 Branch leaves on the spreading branches *strongly squarrose* (upper half bent away from lower half and pointing outward at near 90-degrees), with a broad ovate base, abruptly narrowed above; fascicles with 2 (sometimes 3) spreading, 2-3 pendent branches; plants green, pale green; to yellowish, or whitish..... ***Sphagnum squarrosum***

1' Branch leaves on spreading branches erect and straight to slightly curved, or with their tips spreading at most to about 60 degrees, especially when dry; not strongly squarrose or with a broad ovate base. **2**

2 Branch leaves on the spreading branches erect to spreading in upper portion of plant, slightly squarrose (<60 degrees) in lower portion; fascicles with 3 spreading, 2 pendent branches; plants pale green to yellowish, yellowish-brown, or reddish-brown in sun-grown forms..... ***Sphagnum teres***

2' Not as above in all respects; branch leaves spreading only slightly..... **3**

3 Fascicles with only 3 to 4 branches total, 2 spreading and 1-2 pendent; branch leaves ovate-lanceolate, 1-1.4 mm, imbricate (closely appressed and overlapping like shingles) to moderately spreading, concave, *straight*, strongly involute (rolled inward) near apex; stem leaves large, *lingulate* or lingulate-triangular, 1.2-1.6 (-1.8) mm, apices involute; plants mostly red or red-purple, or mottled red and green..... ***Sphagnum capillifolium***

3' Fascicles with 4 to 6 branches total; plants not red or reddish..... **4**

4 Branch leaves on spreading branches *narrowly* ovate-lanceolate, 0.8-1, mm *straight*; branch fascicles with 2 spreading and 2-3 (sometimes 1) pendent, with *leaves 5-ranked*; stem leaves small, <0.8 mm, short-*triangular* with rounded apices; plants light green, often tinged yellow or brown ..... ***Sphagnum angustifolium***

4' Branch leaves on spreading branches *broadly* ovate, at least some branch leaves *curved* toward one side of branch (secund), such that leaves on one side of branch have their tips curved inward, toward the branch stem axis, and on the other side, with tips curved outward, away from the branch stem axis; branch fascicles with 2-3 spreading and 2-3 pendent stem leaves small, <0.8 (-1.6)[6] mm, triangular-*lingulate*, lingulate, concave with broad, rounded apex, sometimes with small teeth; plants green, yellow, yellow-brown, golden-brown, orange to dark brown..... ***Sphagnum subsecundum***[7]

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[6] Larger stem leaves often 0.8 to 1.0 mm and substantially larger, reaching to 1.6 mm, have been observed in local material attributable to this species by the present investigator. This suggests the reason for previous determinations referred by others as California occurrences of *S. lescurii* Sull. in A. Gray and *S. inundatum* Russow; both of which are indicated by McQueen and Andrus (2007; and pers. comm. Andrus) to occur only in the east, not in California, and furthermore, this material may be referable to *S. subsecundum* which exhibits a broader morphologic variation in this character in California than has been described elsewhere for the species.

[7] Evidently, the concept of this species applies poorly in California. The present investigator notes substantial discrepancies regarding the length of the stem leaves, which appear to be longer than those described for *S. subsecundum s.s.* See also footnote in the discussion for this species.

Descriptions of *Sphagnum* Mosses

Sphagnum angustifolium (Warnstorf) C.E.O. Jensen[8] [Sect. Cuspidata] No plate

(Main reference: McQueen & Andrus 2007 [p 64])
(Additional illustrations: Crum & Anderson 1981 [(as *S. recurvum* var. *tenue*) fig 13 p 45]; Flowers 1973 (as *S. recurvum* var. *tenue*) [pl 1 p 86]; Frey *et al.* 2006 [fig 50 p 136]; McQueen 1990 [p 105 & pls 3, 23, 24, 27, 28]; Smith 1978, 2004 [fig 23 p 97]; Vitt *et al.* 1988 [p 54])

Found in a wide range of habitats (for example in bogs, fens, mires, and as floating mats) at low to high elevations. It occurs in Greenland, North America (south to California, Utah, Colorado, Missouri, and North Carolina) and Eurasia. Plants small and slender in dense, often deep tufts, light green, often tinged yellow or brown. Capitulum is strongly convex in drier-site grown forms; strongly 5-radiate and flat in wetter growing forms. Stem leaves are small, <0.8 mm, and *short-triangular* with rounded apices. Branches 2 spreading and 2-3 (sometimes 1) pendent, with leaves 5-ranked. Branch leaves *narrowly ovate-lanceolate*, 0.8-1 mm, *straight*; Microscopic confirmation: hyaline cells with 1 (2-3 pores/cell at apical ends of cells; chlorophyllose cells triangular in transverse section, and just enclosed on the concave surface.

Sphagnum capillifolium (Ehrhart) Hedwig [Sect. Acutifolia] No plate

(Main reference: McQueen & Andrus 2007 [p 91])
(Additional illustrations: Crum & Anderson 1981 [fig 21 p 62]; Frey *et al.* 2006 [fig 48 p 131]; Malcolm *et al.* 2009 [p 359 (leaf outline only)]; McQueen 1990 [p 93 & pl 18]; Schofield 1992 [p 277]; Smith 1978, 2004 [fig 12 p 69])

Most common and abundant in ombrotrophic (bog) heath vegetation in a broad range of acidic environments, also dense mats and carpets over wet, acidic rocks and peat, especially at higher elevations, less frequent in forested fens. It occurs at low to high elevations. Found in Greenland, North America (south to California, Wyoming, Tennessee, and Virginia), and Europe. Plants are small, compact and stiff. The capitulum is hemispherical; in exposed sites it is red, mottled red and green and in shaded sites it is pale-green to green, tinged with red, or red throughout. Stem leaves lingulate or lingulate-triangular, 1.2-1.6 (-1.8) mm with apices involute. Branch fascicles 2 spreading and 1-2 pendent. Branch leaves ovate-lanceolate, 1-1.4 mm, imbricate to moderately spreading, concave, straight, and strongly involute near apex. Microscopic confirmation: hyaline cells on convex surface with elliptic pores along the edges, concave surface with large round pores in proximal (lower) portions of the leaf.

[8] Reported "remain unknown from California" (Norris and Shevock 2004), but included for California by McQueen & Andrus (2007), and cited by Shaw (2007) as "recently collected in Plumas Co. by (*Dillingham 2335*)."

Sphagnum squarrosum Crome [Sect. Squarrosa] See **Plate 16**

(Main reference: McQueen & Andrus 2007 [p 59])
(Additional illustrations: Crum & Anderson 1981 [fig 8 p 36]; Flowers 1973 [pl 1 p 86]; Frey *et al.* 2006 [fig 47 p 130]; Malcolm *et al.* 2009 [p 27]; McQueen 1990 [p 66 & pl 6]; Schofield 1992 [p 281]; Sharp *et al.* 1994 [fig 6 p 12]; Smith 1978, 2004 [fig 6 p 57])

Typically loose carpets in wet coniferous forests, medium fens, and stream margins, low to high elevations. Found in Greenland, North America (south to California, Arizona, Colorado, Tennessee, and North Carolina), Eurasia, and New Zealand. Plants are tall, robust and stiff, pale to bright green, with a large terminal bud. Branch leaves *strongly squarrose*. Stem leaves large, but *shorter*, 1/2-2/3 as long as branch leaves, ovate-lingulate to oblong lingulate, 1.6-1.8 x 1-1.2 mm, with broad, rounded apex, often fringed at tip. Branch fascicles 2-3 spreading, 2-3 pendent, Branch leaves larger than stem leaves, 1.9-2.8 mm, conspicuously squarrose from ovate-hastate (arrowhead shaped with perpendicular lobe) at the base, and abruptly narrowed into involute-concave (rolled inward) apex. Microscopic confirmation: hyaline cells convex on both surfaces, with *non-ringed* pores at ends and corners of cells, and *ringed* pores on concave (upper) surface (4-8 per cell) and *non-ringed* pores (2-4 per cell) on convex (back) surface. Chlorophyllose cells ovate-triangular, with widest part at or close to the convex surface. Stem cortex 2-3 layers of inflated thin walled cells, branch stems with 1-2 layers of inflated cells.

Sphagnum subsecundum Nees in J. Sturm *et al.*[9] [Sect. Subsecunda] See **Plate 17**

(Main reference: McQueen & Andrus 2007 [p 84])
(Additional illustrations: Crum & Anderson 1981 [fig 16 p 51]; Frey *et al.* 2006 [fig 49 p 134]; McQueen 1990 [p 73 & pl 10]; Schofield 1992 [p 281]; Sharp *et al.* 1994 [fig 6 p 12]; Smith 1978, 2004 [fig 17 p 81])

This species occurs in minerotrophic fens. It is found near the edges of open, poor fens and less commonly in open medium fens. Elevations range from low to high. It is found in North America (south to California and Colorado, and Illinois), Greenland, and Eurasia. Plants area small and slender, often wiry, green, yellow, yellow-brown, golden-brown, orange to dark brown. The capitulum is small. Branch leaves are broadly ovate. A distinctive feature of this species is the strongly curved spreading branches, and the tendency for the branch leaves to be curved toward one side of the branches, especially on the spreading branches. In the described concept of this species, the stem leaves are "small," 0.8 mm or less (-1.0) (but local material with stem leaves usually 1.0 to 1.6mm; see footnotes 7, 8, and 10), triangular-lingulate, lingulate, concave with broad, rounded apex, sometimes with small teeth." However, the local material referable to *S. subsecundum* regularly has stem leaves measuring 1.0 mm up to 1.6 mm (see footnote above). The concept of the species as described does not apply well to Californian

[9] Despite the inclusion of *S. subsecundum* in California by several authors (Norris and Shevock 1994a, b); McQueen and Andrus 2007), Shaw (2007) considers that "Californian specimens determined as *S. platyphyllum, S. contortum, Sphagnum inundatum* and *S. lescurii* , and all records of *S. subsecundum* from California are attributable to *S. 'balboae.'* [a species that has not been described yet]. *Sphagnum 'balboae'* is probably the most common species of *Sphagnum* in California." Andrus (pers. comm. 28 June 2007) indicates "the west coast *subsecunda* is generally in taxonomic flux and the taxonomic work wasn't far enough along to include in The Flora of North America."

material. Microscopic confirmations: Chlorophyllose cells exposed equally on both the concave and convex sides branch leaves; hyaline cells on convex surface with numerous small pores in a continuous row along the sides of the cells. Positive determination of this species complex requires examination of cross sections of branch leaves, branch stems, and main stems. Presence of spiral fibrils in the upper ¼ of the *stem* leaves appears diagnostic, along with the one-cell thickness of inflated, thin-walled cortical cells of the stem leaves. The other common species with spreading leaves *when dry* described herein is *S. teres.*

Sphagnum teres Ångström in C.J. Hartman [Sect. Squarrosa] See **Plate 18**

(Main reference: McQueen & Andrus 2007 [p 59])
(Additional illustrations: Crum & Anderson 1981 [fig 8 p 36]; Frey *et al.* 2006 [fig 47 p 130]; Malcolm *et al.* 2009 [p 358 leaf outline only]; McQueen 1990 [p 68 & pl 7 & 8]; Smith 1978, 2004 [fig 6 p 57])

Found in strongly minerotrophic (fens) and in open to medium rich fens. It is less commonly found in coniferous mires. It is a characteristic species of rich, weakly acidic to slightly basic mires. Elevation ranges from low to high. Found in Greenland, North America (south to California and Colorado, Illinois), and Eurasia. Plants are fairly slender to medium-sized and pale green to yellowish, yellowish-brown, or reddish-brown in sun-grown forms. Branch leaves *slightly* squarrose *when dry, 1-1.4 mm.* Stem leaves large, 1.3-1.8x0.8-1mm, as long or longer than branch leaves, oblong-lingulate to spathulate, with broad, rounded apex, fringed at tip. Microscopic confirmation: *Stem cortex 3-4 layers of inflated thin walled cells*, branch stems one layer of inflated cells. Branch leaves with hyaline *cells bulging* on concave surface, with 4-8 *large*, elliptic *un-ringed* pores on the convex surface, and without pores or 1-4 irregularly rounded *un-ringed* pores per cell on the concave surface; chlorophyllose cells ovate triangular, with the widest part at or close to the convex surface.

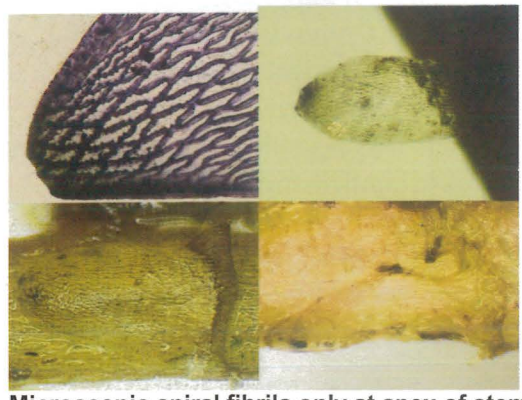
Plate 17

Sphagnum subsecundum

Living plants often pale green to yellowish-brown.

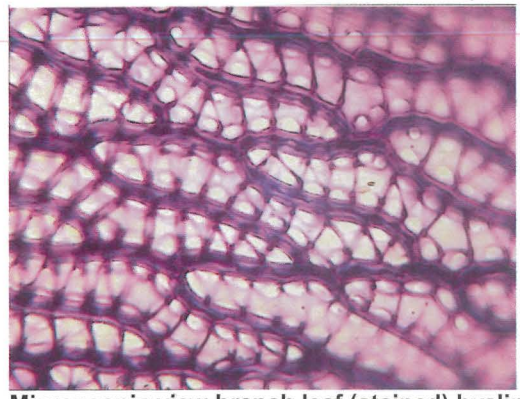
Pendent branch leaves curved in one direction, i.e., subsecund.

Pendent branches curved, and subsecund Leaves point into the curve.



Microscopic spiral fibrils only at apex of stem leaf. Other stem leaf shape variations.

Fascicle (removed) with 3 spreading, and 3 pendent, one very short, indicated by pointer.



Microscopic view branch leaf (stained) hyaline cells, many small pores along edges.

Plate 18

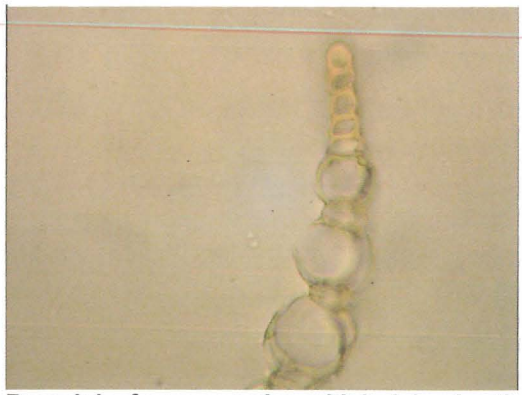
Sphagnum teres

Capitulum.

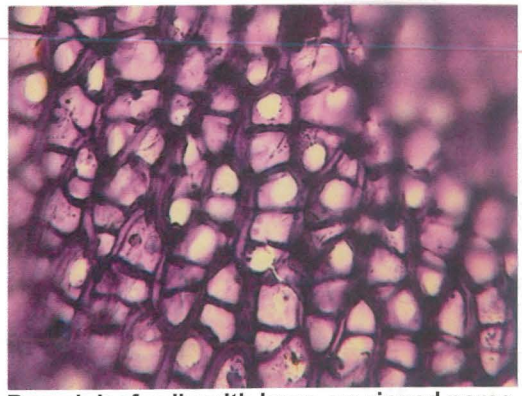
Spreading branches with slightly squarrose branch leaves.

Main stem with fascicles showing 2-3 spreading branches, and 2 appressed pendent branches.

Stem leaf with broad, fringed apex.



Branch leaf cross-section with bulging hyaline cells, elliptic chlorocysts, and thick walled margin cells.



Branch leaf cells with large, un-ringed pores (stained).

Key to Pleurocarpous Mosses

1 Plants erect or upwardly arching, appearing somewhat regularly 1-pinnate in one plane, or plumose (feather-like), however, branches actually arise radially, and are secondarily oriented in one plane; leaves plicate (longitudinally pleated) or wrinkled; stem leaves broadly ovate with a short acumen (point at tip), and with conspicuous masses of paraphyllia, or branched filamentous structures attached to leaf bases and stems ..... ***Helodium blandowii***

1' Plants not plumose; erect or decumbent (laying flat), pinnately or radially branched, but leaves ovate-lanceolate, curved or straight; paraphyllia absent or inconspicuous..... **2**

2 Large plants in loose or dense yellow- to dark-green cushions, usually glossy; irregularly to regularly pinnate; stems prostrate to erect ascending, often stoloniform; stem leaves straight, ovate-lanceolate, concave, plicate; alar cells (those at the basal corners of the leaves) not strongly inflated; costa strong, extending 2/3 to 3/4 of leaf length ..... ***Brachythecium frigidum***

2' Not as above..... **3**

3 Leaves straight, narrowly ovate, oblong or obovate, suddenly rounded at apex, cucullate (concave and curved inwards); plants pale or yellow-green to green, typically rather *straw colored*, sometimes with pink or reddish tints; costa weak, obscure in young pale colored leaves, but evident in older, dark colored ones, reaching 60-90% of leaf length; stems sparsely to densely, more or less radially branched; leaf borne rhizoids common, arising from specialized clear cells called nematogons, or rhizoid intitials, especially on older, dark-colored leaves; (micro: enlarged, clear rhizoid initial cells evident at leaf apices) ..... ***Straminergon stramineum***

3' Stem leaves straight or falcate (curved, sickle-shaped), from ovate or triangular base gradually narrowed toward leaf apex..... **4**

4 Stem leaf costa short, *usually double*, not or hardly visible with a hand lens; stem leaves spreading to squarrose, distinctly furrowed in the acumen, viewed from above, shoots look like miniature "stars;" straight or falcate; alar groups large and distinct; autoicous, hence, frequently with sporophytes..... ***Drepanocladus polygamus*** (not treated herein)

4' Stem leaf costa strong, reaching middle or beyond, visible with a hand lens; dioicous, hence rarely with sporophytes **5**

5 Tomentum, consisting of highly branched rhizoids evident on stem leaves on lower back of costa, leaves straight, long and narrowly triangular, strongly plicate ..... ***Tomentypnum nitens***

5' Tomentum lacking on lower back of costa on stem leaves, leaves not or indistinctly plicate; stem leaves falcate, or straight; alar cells (those in the basal corners of the leaves) evident as a group large and distinctly differentiated and usually visible on torn off leaves; plants sometimes with red colors **6**

6 Shoots radially branched, most distinct when growing with stem erect, in vertical position; plants green or often with clear or sometimes deep red colors, ours with bronze to reddish or vinaceous tones (wine colored), especially on older leaves; sometimes with rhizoids from leaf tips; alar cell groups on stem leaves large, triangular, well delimited, costa strong;

stem leaves more or less concave, leaf margin denticulate (with very small teeth), often visible with hand lens, especially near leaf base and near apex; plants not especially occurring in nutrient-rich habitats..... ***Sarmentypnum exannulatum***

6' Shoots pinnately branched in one plane (distichous); stem leaves straight or falcate, margin entire or almost so; plants *never red*; rhizoids never growing from leaves; often in nutrient-rich and/or calcareous habitats..... 7

7 Alar cell group of inflated cells at the basal corners of the leaves reaching the costa, or almost so..... ***Drepanocladus aduncus***

7' Alar cell group not reaching the costa, extending about half-way across the base of the leaf ..... ***Drepanocladus sordidus***

Descriptions of Pleurocarpous Mosses

Brachythecium frigidum (C. Müller) Bescherelle [Brachytheciaceae] See **Plate 19**

(Main reference: Lawton 1971 [p 290])
(Additional illustrations: Malcolm *et al.* 2009 [p 260]; Flowers 1973 [(as *B. lamprochryseum*) [pl 109 p 451]; Lawton 1971 [pl 162]; Malcolm *et al.* 2009 [p 260]; Sharp *et al.* 1994 [fig 695 p 931]; Vitt *et al.* 1988 (as *B. asperrimum*)[10] [p 99])

This moss grows on soil in very wet places, is seasonally submerged, and is often in or near streams, springs, and lowlands. Elevation range is up to 3,300 m. Found in western North America and Mexico. Large plants in loose or dense yellow- to dark-green cushions, usually glossy. Stems prostrate to erect ascending, irregularly to regularly pinnate, often stoloniform (slender, elongate, runner-like stems, "rooting" by rhizoids). Look primarily at the stem leaves, which are concave, deltoid-ovate to ovate, 2-3 x 0.8-1.5 mm, acuminate (with a long, tapering, sharp tip), deeply plicate (longitudinally pleated or furrowed), decurrent, margins serrulate to serrate, plane (not recurved or revolute). Costa are strong, extending two-thirds to three-quarters the length of the blade, ending in a single abaxial (dorsal or back of leaf) *spine* (a microscopic character exhibited by many species of the genus, but not in other genera considered here). Microscopic confirmation: differentiation of cells in the alar zone (the lower corners of the leaf) of the stem leaves shows *several rows of pellucid (translucent) rectangular cells across the base of the leaf* extending toward the costa, in contrast to more elongate cells above them. The species characteristics are reportedly highly variable, depending upon degree of inundation. Often it is confused with *B. rivulare* (Malcolm *et al.* 2009).

This particular species may present one of the greater challenges to correct field determination. It was selected as a single representative of the genus, being the most frequently encountered in fens during the current study. "*Brachythecium* is one of the most difficult genera of the California mosses" (Norris & Shevock 2004b). Available keys to the genus at local and regional levels are very difficult, and they are not entirely comprehensive in their coverage of species. Unfortunately, no current provisional treatment of the genus is available from

[10] Authors indicate "the correct name for this species may be *Brachythecium frigidum*."

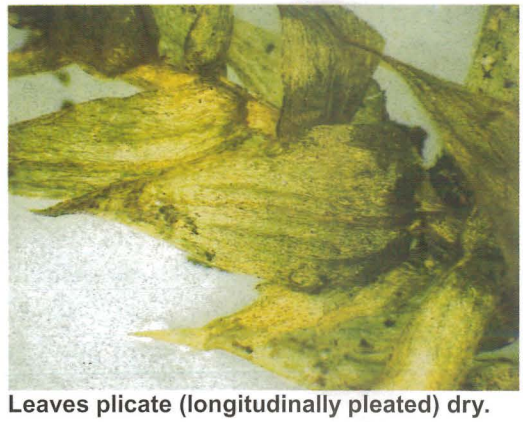
Plate 19

Brachythecium frigidum

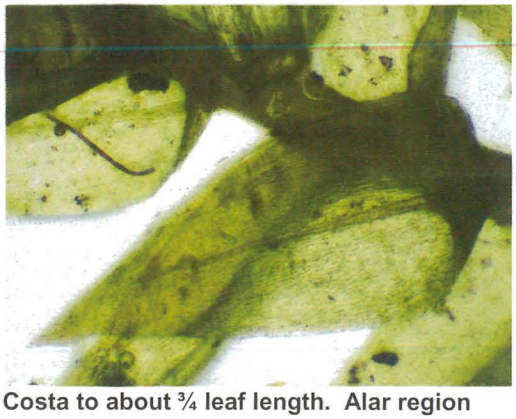
Plants irregularly pinnate, prostrate (scale 1mm).

Plants usually glossy, yellowish to dark green (scale 1 mm).

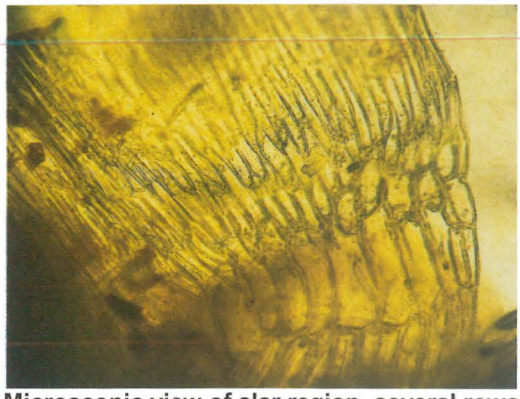
Leaves plicate (longitudinally pleated) wet.



Leaves plicate (longitudinally pleated) dry.



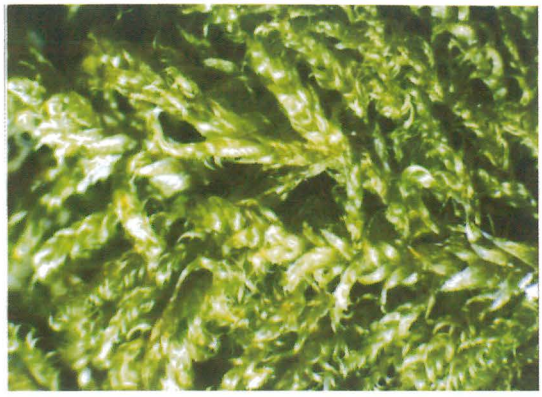
Costa to about ¾ leaf length. Alar region poorly differentiated.

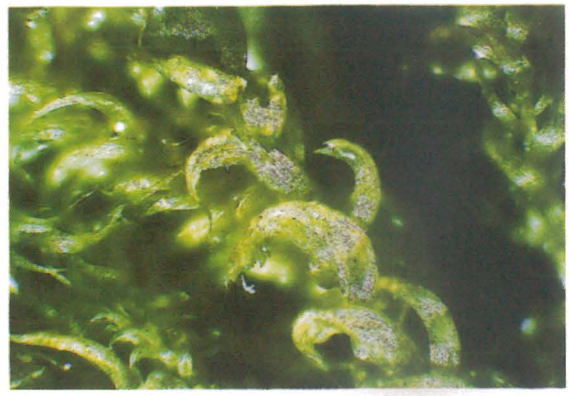


Microscopic view of alar region, several rows of rectangular cells across the base is diagnostic.

Plate 20

Drepanocladus aduncus and *D. sordidus*





Bryophyte Flora of North America. Determination using available keys relies heavily on difficult microscopic characteristics. Thus, objective field recognition of species becomes a matter of developing ongoing familiarity with this genus and the appearance and variation in the local species, along with careful attention to proper collection, coupled with microscopic determination, careful scrutiny, and hopefully, better keys to our species of this genus in the near future.

Drepanocladus aduncus (Hedwig) Warnstorf and ***Drepanocladus sordidus*** (C. Müller Hal.) L. Hedenäs in W.R. Buck. [Campyliaceae] See **Plate 20**

(Main reference: Hedenäs 2003; 2008c, d)
(Additional illustrations: *D. aduncus*: Crum & Anderson [figs 467-468 pp 962, 964]; Flowers 1973 [127 p 499]; Frey *et al.* 2006 [fig 106 p 319); Hedenäs 2003 [(*D. aduncus*) fig 42 p 75; Lawton 1971 [pl 153]; Malcolm *et al.* 2009 [p 232]; Sharp *et al.* 1994 [fig 674 p 904]; Smith 1978, 2004 [fig 258 p 781]; Vitt *et al.* 1988 [p 90]; Watson 1981 [fig 152 p 342]). (Additional illustrations: *D. sordidus*: Hedenäs 2008d [fig 2], 2003 [fig 44 p 78])

Both species are described as inhabiting moderate to mineral rich and nutrient rich wetlands. This would include fens, shores, and ditches, occasionally submerged in pools and lakes, and ox-bow lakes. They are found in polar, boreal, and montane habitats in North America, Eurasia, Mexico, and South America. Elevation ranges from sea level to high mountains. *Drepanocladus aduncus* extends further to West Indies, Africa, Australia, and New Zealand. Five species of *Drepanocladus* are reported from California and the Sierra Nevada, and recognition of species is difficult. Members of the species complex can be very abundant, and even dominant in some of our local fens. The ovate-lanceolate leaves are most often strongly falcate-secund (curved, and turned to one side), but are occasionally relatively straight, with sharp-pointed tips. They are medium sized, glossy, green, yellow-green, golden, yellowish or brownish (but *not reddish*), and pinnately branched. The leaf midrib (costa) is ½ to ¾ of the leaf length, ending well below apex. The leaf margins are entire (smooth, without teeth). Compare these species with *Sarmentypnum exannulatum*, which branches radially, and usually shows some bronze, vinaceous, or clearly reddish colors, especially on the older leaves.

Helodium blandowii (Weber & D. Mohr) Warnstorf [Helodiaceae] See **Plate 21**

(Main references: Lawton 1971 [p 261]; Crum & Anderson 1981 [p 912])
(Additional illustrations: Crum & Anderson 1981 [fig 440 p 913]; Flowers 1973 [pl 90 p 400]; Frey *et al.* 2006 [fig 102 p 309]; Lawton 1971 [pl 145]; Malcolm *et al.* 2009 [p 247]; Smith 1978, 2004 [fig 248 p 753]; Vitt *et al.* 1988 [p 85])

This species is widespread in boreal areas of the northern hemisphere, including North America (south to California, Arizona, and Colorado), Greenland, northern and central Europe, and Siberia. It is rare[11] in our region, and been found only recently in the Sierra Nevada of

[11] It is included on the California Department of Fish and Game's list of Special Bryophytes. The California Bryologists Working Group recommended (in 2010) that it remain on the R5 FS Regional Foresters list of sensitive plant species.

California and Nevada, in several sites primarily on the east side from Tulare, Fresno, Mono and Washoe counties, and in the Sweetwater Mountains (California) and Jarbidge Mountains (Nevada). It inhabits calcium-rich wet habitats, including brushy thickets along streams, the edges of swamp forests, around alpine lakes, and in fens. They are robust plants forming dense, soft, yellow, yellow-green, or light-green masses. Contrary to published descriptions that the branching is pinnate, in one plane, this observer notes that the branching is actually semi-radial; the branches arising only on one hemispheric side of the stem, and these branches are secondarily oriented in one plane, especially below the ends of the main stem, resulting in the distinctive 1-pinnate (plumose) appearance. Viewed either from the top, or head-on toward the apex, the branching appears quite radial, and this coupled with the pale color sometimes suggests *Sphagnum,* but the closely pinnate secondary arrangement of the lower branches readily separates it from the fasciculate branching of *Sphagnum.* The really distinctive feature of this moss is the copious masses of branched filamentous paraphyllia that cover the main stem and branches, and similar cilia on the basal margins of the leaves. This feature is best seen on dry to slightly moist plants, as the paraphyllia are obscured by the surface film of water on wet plants. Unlike dark-colored rhizoids that often form a dense tomentum over the stems of many other mosses found in fens, the paraphyllia and marginal cilia are very pale yellowish. The stem leaves are broadly ovate, to about 1.5 mm, with a strong costa reaching 4/5 of the length. The branch leaves are narrowly ovate and about half the size of the stem leaves. The leaf margins are revolute, serrate (sawtooth) to serrulate (minute sawtooth) above, and tips are sharp, ending in a single cell. The leaves are rather irregularly wrinkled, both when wet and dry. In microscopic view, the leaf cells have tall bumps (papillae) at their upper ends, and this probably adds to an opaque appearance of the leaves in gross view.

Sarmentypnum exannulatum (Schimper) Hedenäs[12] [<= ***Warnstorfia exannulata*** (Schimper) Loeske in Nitardy; <=***Drepanocladus exannulatus*** (B.S.G.) Warnstorf] [Calliergonaceae]
See **Plate 22**

(Main references: Hedenäs 2008a; 2008b; 2008e (as *S. e.*); 2003 [p 55] (as *W. e.*)
(Additional illustrations: Crum & Anderson (as *Drepanocladus exannulatus*) [fig 469 p 966]; Flowers 1973 (as *D. e.*) [pl 129 p 503]; Frey *et al.* 2006 (as *D. e.*) [fig 106 p 319]; Hedenäs 2003 [fig 31 p 55]; Lawton 1971 [(as *D. e.*) pl 153]; Malcolm *et al.* 2009 [p 244]; Sharp *et al.* 1994 [(as *D.e.*) fig 674 p 904]; Smith 1978, 2004 [(as *W. e.* fig 259 p 783])

Sarmentypnum exannulatum occurs in intermediately mineral-rich fens, around springs and late melting snowbeds, and is sometimes submerged in lakes. Elevation ranges from lowlands to the high-alpine regions of the mountains, and in Arctic and Antarctic areas, from sea level to 4,150 m. It is widespread in northern and southern temperate and sub-polar zones, and occurs in many mountain areas in the tropical and subtropical zones. Found in North America, Mexico, South America, Greenland, Eurasia, Africa, Australia, and New Zealand. Among species treated here, it most closely resembles species of the *Drepanocladus aduncus* complex, and one must be careful to observe the differences in branching pattern and sometimes subtle coloration. Plants

[12] According to Hedenäs (2008a, 2008b, 2008e) "*Sarmentypnum* and *Warnstorfia* are well separated based on molecular evidence and morphological features." "*Sarmentypnum* frequently develops red coloration [rarely in *Warnstorfia*], and are found in intermediately mineral-rich rather than mineral-poor situations [as are *Warnstorfia*]."

are medium-sized green, yellowish, or when exposed to sun often with red or dark red coloration. The author observes distinct bronze through vinaceous (wine colored) tones in the local material, best observed in the previous-years growth on portions of the stems and branches. Stem leaves are falcate, usually strongly so, rarely straight, gradually narrowed to acuminate (tapered to a long, sharp apex) from an ovate or ovate-triangular base, concave; margins distinctly denticulate (very finely toothed) at apex, base, or both; costa ending 60-95% of the way up the leaf; alar cells in a distinctly delimited, transversely triangular group that reaches the costa or almost so. At the microscopic level, rhizoid initials, or nematogons close to the leaf apices are very helpful in distinguishing *Sarmentypnum* from members of the *Drepanocladus aduncus* complex, which always lack such initials. Unfortunately, these rhizoid initials seem rarely to actually produce rhizoids at the tips of the leaves that could be seen in the field with a hand lens. For field identification, one must observe that *Sarmentypnum* species are actually radially branched, whereas *Drepanocladus* species are branched in two-ranks, or distichously. It's best to observe this by viewing the tops or ends of plants downward, toward the stem apices. The branching along the radial axes is sparse, but three branching axes are enough to suspect the radial pattern. As viewed using a strong hand lens, the leaf margins are *minutely* toothed (denticulate) toward the tip, or base, or both, unlike *Drepanocladus,* which has smooth (entire) leaf margins. Finally, *Drepanocladus* "never" develops red colors.

Straminergon stramineum (Bridel) Hedenäs [<= *Calliergon s.* (Bridel) Kindberg] [Calliergonaceae] See **Plate 23**

(Main references: Hedenäs 2008b; 2008f; 2003)
(Additional illustrations: (Flowers 1973 (as *Calliergon s.*) [pl 121 p 484]; Frey *et al.* 2006 (as *Calliergon s.*) [fig 107 p 322]; Hedenäs 2003 [fig 36 p 63]; Hedenäs 2008f [fig 1]; Lawton 1971 (as *Calliergon s.*) [pl 149]; Malcolm *et al.* 2009 [p 243]; Smith 1978, 2004 [fig 260 p 785]; Vitt *et al.* 1988 [(as *Calliergon s.*) p 89]; Watson 1981 [fig 159 pp 352])

This moss is widespread and is known to grow in mineral-rich to mineral-poor (but not calcareous), and nutrient-poor to nutrient-rich fens, along shores, or in irrigated rocks, at low to high elevations. Found in North America, South America, northern Eurasia, Africa, New Zealand, and Australia. It has whitish to yellowish green, pale *straw-colored* or stramineous shoots, or often with slightly pinkish[13] to vinaceous (wine colored) tones, becoming darker wine colored on older leaves below the straw colored or pinkish ones. Stems are sparsely branched. Leaves are straight, oblong, ovate or narrowly ovate, distally *suddenly narrowed to a rounded* and often with a cucullate (hood-like, apex concave, curved inwards) apex. The costa is single, *weak*, difficult to discern, and end 60-90% up the leaf (local material often shorter). Alar cells are thick walled at margin, more inflated interior. The rhizoid initials, or nematogons at apex of the leaves frequently produce rhizoids. Microscopic confirmation: nematogons without rhizoid initials are common; leaf cells at apex are short rectangular, compared to elongate cells below.

[13] According to Malcolm et al. (2009 p 243, *Straminergon stramineum* is "never tinged with red." However, the plates included therein *clearly* show pink to red colors in the leaves of this species.

Tomentypnum nitens (Hedwig) Loeske [Amblystegiaceae][14] See **Plate 24**

(Main references: Faubert 2004; Hedenäs 2003 [p 71])
(Additional illustrations: Crum & Anderson 1981 [fig 496 p 1016]; Flowers 1973 [pl 11 p 157]; Frey *et al.* 2006 [fig 109 p 329]; Hedenäs 2003 [fig 40 p 70, fig 17a p 32 (stem x-s)]; Lawton 1971 [(as *Homalothecium nitens*) pl 173]; Malcolm *et al.* 2009 [p 276]; Smith 1978, 2004 [fig 263 p 793]; Vitt *et al.* 1998 [p 97])

These are large, erect, golden yellow plants forming loose to dense peatland lawns or hummocks, in mineral-rich and sometimes somewhat nutrient-rich fens, and sometimes in other rich wetland habitats. Common and widespread across boreal and arctic areas of the Northern Hemisphere, reaching the high Arctic and extending south to New Mexico, and only recently found in California, and rare[15] here in high mountains. It is pinnate or subpinnately branched in one plane and very feathery (plumose). Leaves 2-4 mm long, *strongly plicate, long-lanceolate, straight*, leaf apex long acuminate: mostly with numerous, highly branched rhizoids from the proximal (lower) abaxial (back) surface of the costa, and with thick *tomentum* on one side of the stem.

[14] Family placement is uncertain. According to Norris & Shevock (2004) *Tomentypnum* "has traditionally been placed in a much expanded *Homalothecium* [Brachytheciaceae]." "The recent work of Hedenäs, however, requires placement in the Campyliaceae..." According to Hedenäs (pers. comm. April 24, 2010) "We still don't know exactly where *Tomentypnum* belongs." "Unfortunately, the analysis by Vanderpoorten et al. (2002, Molecular Phylogenetics and Evolution) could not place *Tomentypnum* in a (known) family. However, with the pragmatic approach of BFNA, it is placed in Amblystegiaceae."

[15] Because of its recent discovery and rarity, it has not yet been placed on California Department of Fish and Games list of Special Bryophytes (2009). The California Bryologists Working Group recommended (in 2010) that it be placed on the FS Pacific Southwest Regions' list of species of Special Concern.

Plate 21

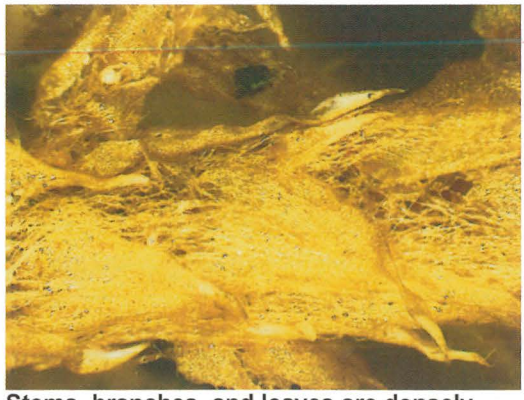
Helodium blandowii

Plants somewhat erect, yellowish to green, in masses resembling *Sphagnum*.

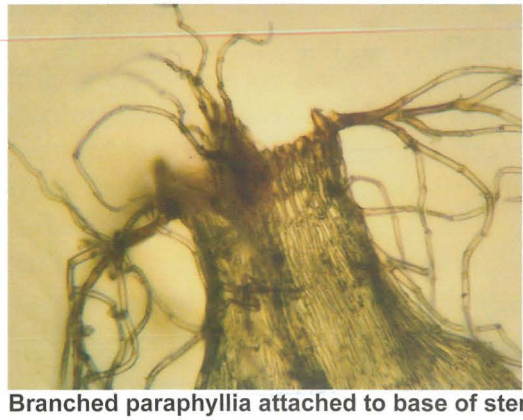
Branching is semi-radical.

Branching appears plumose, but branches are actually attached semi-radical, with some attached on dorsal side of the main stem.

Stem leaves ovate, irregularly wrinkled, with cilia on basal margin.



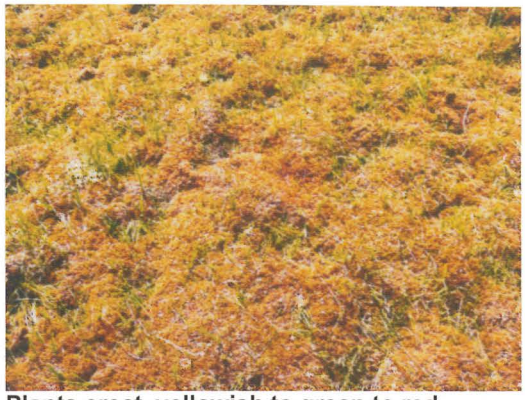
Stems, branches, and leaves are densely clothed with pale-colored paraphyllia and cilia.



Branched paraphyllia attached to base of stem leaf, and cilia along the basal margin.

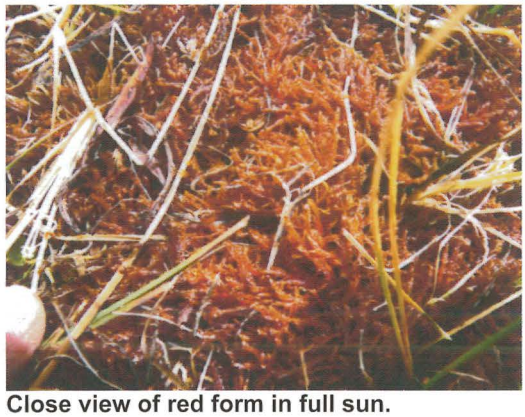
Plate 22

Sarmentypnum exannulatum



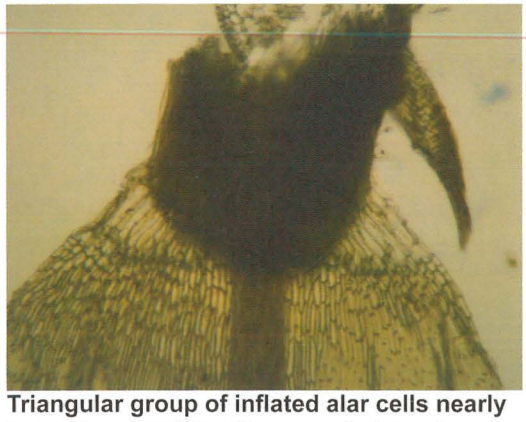
Plants erect, yellowish to green to red.

Branching is radical, unlike *Drepanocladus*.

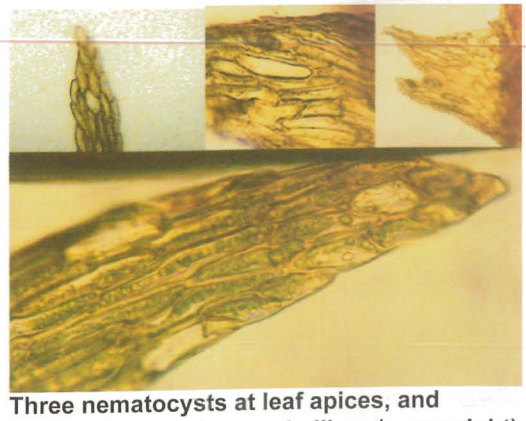


Close view of red form in full sun.

Coppery to bronze and wine colors are common.



Triangular group of inflated alar cells nearly to costa resembles *Drepanocladus aduncus*.

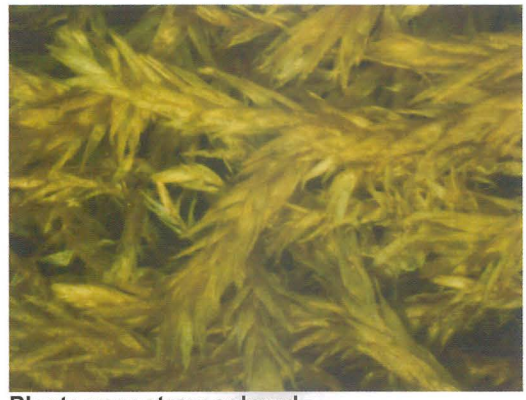


Three nematocysts at leaf apices, and diagnostic pseudoparaphyllium (upper right).

Plate 23

Straminergon stramineum

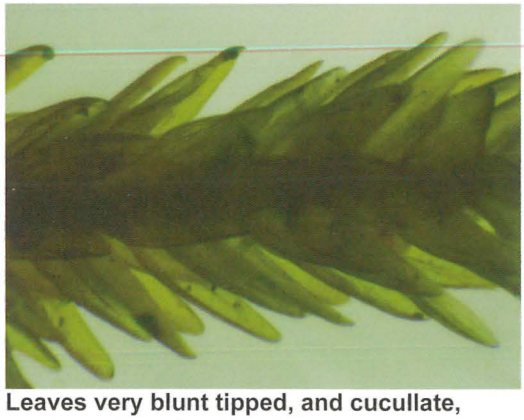
Living plants yellow green, glossy, sparsely branched (with *Helodium*, darker brown plants).



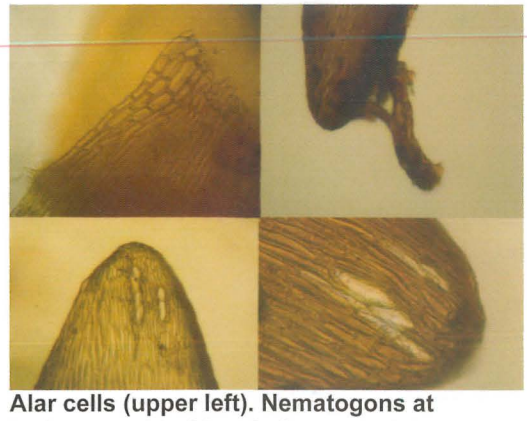
Plants very straw colored.

Often tinged with a slight pinkish to wine color.

Leaves very blunt tipped, costa weak and not easily seen.



Leaves very blunt tipped, and cucullate, costa weak and not easily seen.



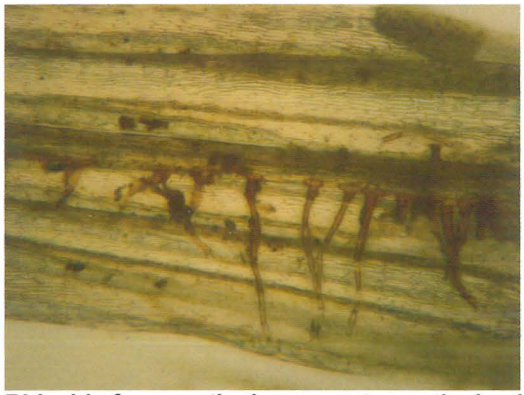
Alar cells (upper left). Nematogons at leaf apex, with rhizoids (upper right).

Plate 24

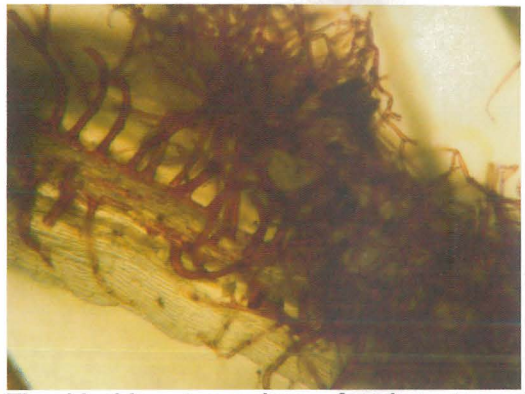
Tomentypnum nitens

Plants are strongly pinnate, light colored with sharp pointed stems and branches and straight, lanceolate leaves.

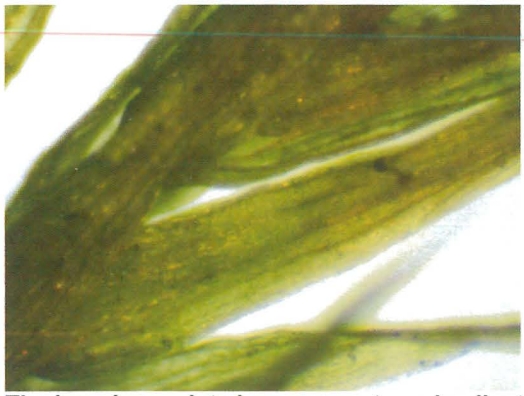
The lanceolate leaves are erect, and the main and branch apices are very sharp pointed.



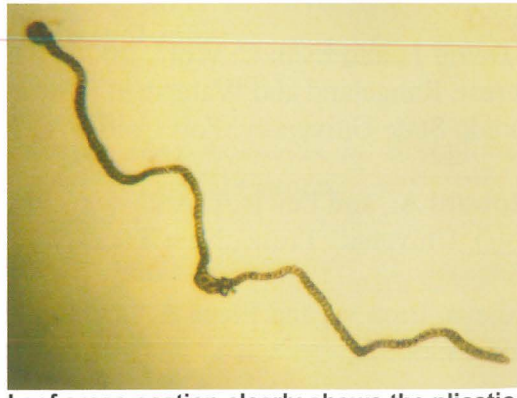
Rhizoids form on the lower costa, on the back of the leaves.



The rhizoids get very dense, forming a tomentum on the backs of the leaves.



The long lanceolate leaves are strongly plicate, i.e. longitudinally pleated.



Leaf cross-section clearly shows the plications. Also note the revolute leaf margin.

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[16] Citations indicated by (*) are included in the already published Volume 27, and can be accessed in their entirety at http://www.mobot.org/plantscience/bfna/bfnamenu.htm Go to the menu therein, click on "The Treatments," the "Summary of the Treatments," then click under Volume 1, "efloras."

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V. Photographic Notes

Most photos depict plants in the field that were observed and collected by the author. Field macrophotographs were mostly taken using a Panasonic Lumix Z-5 camera; a few were taken with a Nikon Coolpix P100. Laboratory macrophotographs used a Wesco stereoscopic dissecting scope equipped with overall zoom 6.5X to 45X magnifications, and photomicrographs used a Zeiss Standard model compound microscope with 40X, 100X, and 400X magnifications available. Both scopes are equipped with trinocular heads that enabled macro- and photomicrography of the specimens using a Nikon Coolpix 995 digital camera, mediated by a Coolpix microscope adapter for a 23 mm diameter microscope eyepiece, part ADPT-CP-23 made by MVIA. All photomicrographs were taken at "high" quality 3.34 megapixels specific for the Coolpix 995. The size of the ".tif" images stored on "CF" media by the camera is mostly less than 10 megabytes. Many photographs taken repeatedly at slightly differing focus levels in the scopes were enhanced using the Helicon Focus stacking program, and subsequent digital editing utilized the Helicon Filter program. All photographs remain the property of the author, with explicit permission granted to the Forest Service for their use in this publication. All other uses require additional permissions from the author.

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